



Cyprus
University of
Technology

Faculty of Health Sciences

Doctoral Dissertation

COGNITIVE-LINGUISTIC PROFILING OF GREEK
SPEAKERS WITH PARKINSON'S DISEASE

Emmanouil Anyfantis

Limassol, September 2022

CYPRUS UNIVERSITY OF TECHNOLOGY
FACULTY OF HEALTH SCIENCES
DEPARTMENT OF REHABILITATION SCIENCES

COGNITIVE AND LINGUISTIC PROFILE OF GREEK
SPEAKERS WITH PARKINSON'S DISEASE

Emmanouil Anyfantis

Limassol, September 2022

Acknowledgements

As they say, completing a dissertation is a long hard road. For me, this dissertation would never have been possible without the help and support of many people.

First and foremost, I would warmly like to thank from the bottom of my heart my advisor, Professor Dr. Maria Kambanaros, for her endless encouragement, inspiration, and support throughout the last few years. She was always there to push me forward and tell me the right words to keep going with my research project.

Also, I am truly grateful for the personal, professional, and generous support of Dr. Spiridon Konitsiotis, Professor of Neurology at the Medical School of Ioannina. My research would never have been possible without his help and support.

Of course, I would like to thank all my dear friends who took care of the essential spiritual support to complete this study.

Finally, I would like to thank my family for their love, support, and infinite patience over these particularly stressful years. Without their support, this long uphill climb would not be possible.

ABSTRACT

Parkinson's disease (PD) is a progressive neurodegenerative disease that is characterized by movement-related (motor) symptoms. In addition to motor symptoms, recent research has investigated the role of non-motor symptoms in PD such as cognitive and language disturbances. A growing number of studies suggest that language deficits are common in individuals with PD in the early stages of the disease. The literature has documented language disorders characteristic of PD progression in several different languages. However, a limited number of studies have explored the cognitive-linguistic profile of Greek-speaking individuals with PD.

The main aim of the research reported in this thesis was to explore cognitive and language deficits in non-demented Greek-speaking individuals with idiopathic PD. For this purpose, the cognitive and language abilities of a group of 24 participants with PD were compared with that of 15 healthy controls matched for sex, age and education. A set of neurocognitive and language measures were administered. The neurocognitive tasks included attention span, verbal working memory, set-switching, executive functions, and semantic memory. The language tasks included a confrontation naming task of nouns and verbs, a sentence repetition task, and a metaphor processing task.

The results revealed that the PD group performed significantly lower on executive functions tasks (i.e., Trail making Test-A and B, and phonemic fluency) compared to healthy controls. However, no significant difference was observed between the two groups on verbal working memory measures and semantic fluency.

Regarding the language tasks, the results showed that the PD group had greater difficulty in retrieving nouns and verbs and processing metaphors and idioms compared to healthy controls. No significant difference was found on a sentence repetition task.

Moreover, the effect of instrumentality and verb-noun name relation on action naming ability in the PD group was explored. The Greek Object and Action Test (GOAT) a picture-based assessment of common nouns and verbs was administered. Two types of verbs were tested. This included semantically complex "heavy" verbs (i.e., instrumental verbs e.g., "sweeping") and semantically "light" verbs (i.e., non-instrumental verbs e.g., sitting). The PD group performed better on naming instrumental verbs than non-instrument indicating that instrumentality has a positive effect on verb naming.

Multiple regression analyses revealed that the neurocognitive variables of set switching and working memory and the psycholinguistic factor of picture complexity predicted the verb naming accuracy.

This is the first study exploring the cognitive-linguistic profile of Greek-speaking individuals with PD. The results are consistent with the findings of previous studies that revealed language disorders in this population. Future clinical studies with larger PD samples should combine neurocognitive, linguistic and neuroimaging testing to further explore the cognitive-linguistic profile of PD in the early stage so that speech pathologists can determine evidence-based treatment options.

Keywords: Parkinson's disease, instrumentality, word retrieval deficits, sentence processing, metaphor processing, Greek language

ΠΕΡΙΛΗΨΗ

Η Νόσος του Πάρκινσον (ΝΠ) είναι μία νευροεκφυλιστική νόσος η οποία χαρακτηρίζεται από κινητικές δυσκολίες. Πρόσφατες μελέτες έχουν διερευνήσει τον ρόλο των μη-κινητικών διαταραχών όπως των γνωστικών και γλωσσικών ελλειμμάτων που συχνά συνυπάρχουν με τις κινητικές δυσκολίες. Τα ευρήματα από μεγάλο αριθμό κλινικών μελετών έχουν υποστηρίξει ότι οι γλωσσικές διαταραχές είναι συχνές στα πρώιμα στάδια της νόσου. Επίσης στην βιβλιογραφία έχουν περιγραφεί οι γλωσσικές διαταραχές σε διαφορετικές γλώσσες. Παρόλα αυτά, περιορισμένος αριθμός μελετών έχουν διερευνήσει το γνωστικό-γλωσσολογικό προφίλ σε ομιλητές της Ελληνικής γλώσσας με ΝΠ.

Ο σκοπός της παρούσας μελέτης ήταν να διερευνήσει το γνωστικό και γλωσσικό προφίλ των ατόμων με ΝΠ. Στην παρούσα μελέτη συμμετείχαν 24 άτομα με ΝΠ και 15 υγιείς άτομα ως ομάδα ελέγχου. Για την διερεύνηση του γνωστικού και γλωσσικού προφίλ χορηγήθηκαν νευροψυχολογικές και γλωσσικές δοκιμασίες.

Οι νευροψυχολογικές δοκιμασίες που χορηγήθηκαν ήταν δοκιμασίες προσοχής, μνήμης εργασίας, φωνημικής και σημασιολογικής λεκτικής ροής και της οπτικό-νοητικής ιχνηλάτησης (μέρος Α και Β). Οι γλωσσικές δοκιμασίες είχαν ως στόχο να αξιολογήσουν την ικανότητα κατονομασίας ουσιαστικών και ρημάτων, την ικανότητα επανάληψης προτάσεων και την ικανότητα επεξεργασίας μεταφορών και ιδιωματισμών.

Σύμφωνα με τα αποτελέσματα της μελέτης οι δύο ομάδες συμμετεχόντων, όσον αφορά τις γνωστικές λειτουργίες είχαν σημαντικές διαφορές στην φωνημική ροή και στην οπτικο-νοητική ιχνηλάτιση (μέρος Α και Β). Σχετικά με τις γλωσσικές δοκιμασίες τα άτομα με ΝΠ εμφάνισαν μεγαλύτερη δυσκολία στην κατονομασία ουσιαστικών και ρημάτων και στην επεξεργασία των μεταφορών και ιδιωματισμών. Πιο συγκεκριμένα, είχαν μεγαλύτερη δυσκολία στην κατονομασία ρημάτων σε σχέση με τα ουσιαστικά. Επίσης είχαν μεγαλύτερη ακρίβεια στην κατονομασία των ενόργανων ρημάτων σε σύγκριση με τα ανόργανα.

Η παρούσα μελέτη είναι η πρώτη μελέτη που διερεύνησε το γνωστικό-γλωσσολογικό προφίλ ομιλητών της Ελληνικής με ΝΠ. Τα ευρήματα της μελέτης συμφωνούν με ευρήματα προηγούμενων ερευνών που έχουν καταγράψει γλωσσικές διαταραχές σε άτομα με ΝΠ. Μελλοντικές μελέτες θα πρέπει να διερευνήσουν περαιτέρω τις γλωσσικές διαταραχές σε αυτόν το κλινικό πληθυσμό με μεγαλύτερα δείγματα ατόμων

με ΝΠ στα αρχικά στάδια της νόσου. Επίσης ο συνδυασμός νευρογνωστικών, γλωσσικών και νευροαπεικονιστικών δεδομένων θα οδηγήσει στην δημιουργία νέων τεκμηριωμένων θεραπευτικών προσεγγίσεων οι οποίες είναι αναγκαίες για την αποκατάσταση των γλωσσικών διαταραχών σε αυτό τον πληθυσμό.

TABLE OF CONTENTS

ABSTRACT.....	IV
ΠΕΡΙΛΗΨΗ.....	VI
TABLE OF CONTENTS.....	VIII
LIST OF TABLES.....	XII
LIST OF FIGURES.....	XIV
LIST OF ABBREVIATIONS.....	XV
Chapter 1: Introduction.....	1
Chapter 2: Pathophysiology and clinical characteristics of Parkinson's disease.....	4
2.1 Introduction.....	4
2.2 Clinical Characteristics.....	4
2.2.1 Non-motor characteristics of PD.....	5
2.3 Clinical diagnostic criteria.....	7
2.4 Anatomy of the Basal Ganglia.....	8
2.5 Neuropathology of PD.....	9
2.6 Frontostriatal circuits.....	9
2.7 Clinical Scales for PD.....	12
2.7.1 Hoehn and Yarn Scale.....	12
2.7.2 The Unified Parkinson's disease Rating Scale (UPDRS).....	12
Chapter 3: Cognitive deficits in PD.....	14
3.1 Introduction.....	14
3.2 Cognitive functions in PD.....	14
3.2 Cognitive deficits in early stages.....	15
3.2.1 Mild Cognitive Impairment in Parkinson's disease (MCI-PD).....	16
3.2.2 Dementia in Parkinson's disease.....	17
3.3 Executive Dysfunction in PD.....	18
3.4 Verbal fluency deficits.....	19
3.5 The Dual Syndrome Hypothesis.....	21

3.6 The neural underpinnings of the cognitive impairment in PD	21
3.7 Summary	21
Chapter 4: Language disorders in Parkinson’s disease	23
4.1 Introduction.....	23
4.2 Clinical characteristics of language disorders.....	23
4.3 Language disorders in the early stages of PD	24
4.4 Underlying cognitive deficits in linguistic deficits	25
4.5 Language and Cognition Dysfunction	26
4.6 Metaphor and idiomatic language processing deficits	28
4.7 Neural underpinning of language deficits in PD.....	30
4.8 Action-related language processing deficits in PD	31
4.8.1 Noun-verb processing differences.....	32
4.8.2 Stages of confrontational naming.....	33
4.8.3 Noun-verb processing deficits in PD	37
4.8.4 The role of semantic variables in verb processing deficits.	39
4.8.5 Neural basis for verb retrieval language disorders in PD.....	41
4.8.6 Word production and executive functions	43
4.8.7 Semantic complexity and verb retrieval ability.....	45
4.8.8 Words related to tools	47
4.9 Conclusion	48
Chapter 5: Research aims.....	50
5.1 Studies in Greek Language	50
5.2 Grammatical features of Greek Language	50
5.3 Research Questions	52
Chapter 6: Methodology	55
6.1 Participants.....	55
6.2 Materials.....	57
6.2.1 Neuropsychological tasks.....	57

6.2.2 Language Tasks.....	59
6.2.2.1 The Greek Object and Action Test.....	59
6.2.2.2 The Greek Sentence Repetition Test (GrSRepT).....	62
6.2.2.3 Test of Idioms and Metaphors (TIM).....	63
6.3 Procedures.....	64
Chapter 7: Results	65
7.1 Demographic variables.....	65
7.2 Performance on neurocognitive tasks	65
7.3 Performance on the GOAT (noun-verb naming)	66
7.4 Quantitative and qualitative analysis of naming error types	68
7.5 Performance on the repetition test and the idiom-metaphor processing task.....	70
7.6 Correlation and regression analyses.....	71
7.6.1 Correlation analyses	72
7.8 Contribution of psycholinguistic variables on naming performance	74
Chapter 8: Discussion	77
8.1 Cognitive functions in PD.....	77
8.1.1 Verbal fluency in PD.....	78
8.1.2 Set switching abilities in PD	80
8.2 Noun and verb naming abilities in PD	80
8.2.1 Noun and verb comprehension in PD	81
8.2.2 Noun and verb production.....	82
8.3 Sentence Repetition abilities in PD.....	91
8.4 Idiomatic and Metaphor processing abilities in PD	93
8.5 Synthesis of results.....	94
8.6 Contribution of Executive Functions in naming	96
8.7 Summary	97
Chapter 9: Clinical Implications	99
9.1 A proposed assessment for the cognitive-linguistic functions in PD.....	100

9.1.1 PD and the ICF model.....	102
9.2 Limitations	105
9.3 Future directions	106
Appendix A.....	131
Target nouns and verbs on the Greek Object and Action Test (GOAT).....	131
Appendix B	135
Greek Sentence Repetition Test.....	135
Appendix C	138
Test of Idioms and Metaphors (TIM).....	138
Appendix D.....	145
Examples of the picture stimuli.....	145

LIST OF TABLES

Table 2.1: Definitions of the motor symptoms in PD	5
Table 2.2: Definitions of the major non-motor symptoms of PD	7
Table 2.3: Diagnostic symptoms of Parkinson Disease	7
Table 3.1: Definitions for each component of executive functions.	18
Table 4.1: Key findings from studies reporting on language disorders in PD	27
Table 4.2: Key findings from reported studies on metaphor and idiomatic language processing	30
Table 4.3: Key findings from the reported studies on verb-noun processing deficits in PD	42
Table 4.4: Key findings from reported studies on the impact of executive functions in verb retrieval	44
Table 4.5: Studies reporting on the effects of instrumentality and name relation on verb retrieval	46
Table 4.6: research on the effects of instrumentality and verb-noun name relation on verb retrieval in stroke induced aphasia.....	47
Table 6.1: Demographic data for participants by group.	56
Table 6.2: Disease Characteristics of individuals with Parkinson’s disease.....	57
Table 6.3: Neurocognitive and Linguistic Measures	63
Table 7.1: Performance on neurocognitive measures for PD and healthy control groups	66
Table 7.2: Mean percentage correct on noun and verb naming and comprehension for the PD and healthy control groups across subtests of the GOAT.	67
Table 7.4: Error type definitions	69
Table 7.5: Error analysis for verb and noun naming for the PD group.....	69
Table 7.5: Mean percentage correct for group performance on the TIM.....	70
Table 7.6: Mean percentage correct group performance on the Sentence Repetition Test	70
Table 7.7: Correlation analyses between the linguistic and non-linguistic cognitive abilities ...	73
Table 7.8: Mean values (SD) of psycholinguistic characteristics for noun and verb pictures of GOAT	76
Table 7.9: Multiple regression analyses: contributions of psycholinguistic variables on GOAT naming accuracy in the PD group	76

Table 9.1: ICF components for individuals with PD 105

LIST OF FIGURES

Figure 2.1: Schematic representation of the course of non-motor symptoms that occur throughout the course of PD	6
Figure 2.5: Frontal-subcortical networks	10
Figure 2.6: Hoehn and Yarn Scale	12
Figure 2.7: The Motor Examination components of the Unified Parkinson’s Disease Rating Scale	13
Figure 3.1: Three distinguished neurocognitive stages in PD progression	17
Figure 4.1: Lexical model of word production	34
Figure 4.2: The Blueprint for the Speaker model of speech production	35
Figure 5.1: Grammatical features of the Noun lemma.....	52
Figure 5.2: Grammatical features of Verb lemma.....	52
Figure 7.1: Overall performance on neurocognitive measures between the PD group and the HC group.	66
Figure 7.2: Overall performance on the GOAT between the PD group and HCs for single word noun and verb production.....	67
Table 7.3: Pairwise Comparisons between the three types of verbs	68
Figure 7.3: Types of errors produced for content and function words for both groups.	71
Figure 7.4: Types of errors produced for content and function words for every type of sentence.	71
Figure 8.1: Semantic representation of the instrumental verb ‘building’.....	85
Figure 8.2: Naming of the noun “hammer”	90
Figure 8.3: Semantic errors of naming of the noun “hammer”	91
Figure 8.4: Interaction between cognitive and linguistic deficits in PD	96
Figure 9.1: Flowchart of evaluation of cognitive and linguistic functions in PD	101

LIST OF ABBREVIATIONS

PD: Parkinson's disease

PD-MCI: Parkinson disease Mild cognitive deficits

BG: basal ganglia

NMS: non-motor symptoms

H&Y: Hoehn and Yahr scale

UPDRS: Unified Parkinson's disease Rating Scale

MG: Modern Greek

PDD: Parkinson's Disease Dementia

MMSE: Mini Mental State Examination

HCs: Healthy controls

TMT-A: Trail Making Test-A

TMT-B: Trail Making Test -B

SF: Semantic fluency

PF: Phonemic fluency

EF: Executive functions

DST: Digit Span Test

DSF: Digit Span Forward

DSB: Digit Span Backward

GOAT: Greek Object Action Test

IN+NR: Instrumental nouns with a name relation

IN-NR: Instrumental nouns without a name relation

NIN: No instrumental nouns

IV+NR: Instrumental verbs with a name relation

IV-NR: Instrumental verbs without a name relation

NIV: no instrumental verb

SRepT: Sentence repetition Test

TIM: Test of Idioms and Metaphors

Chapter 1: Introduction

Parkinson's disease (PD) is a neurodegenerative disease that is characterized by motor and non-motor symptoms. Initially, it was considered a pure motor disorder for many years (Parkinson, 2002). However, a considerable body of clinical data has explored the pathophysiology of non-motor symptoms (Schapira, Chaudhuri, & Jenne, 2017).

Cognitive deficits and communication disorders are among the most common of non-motor symptoms that accompany the disease even in the earliest stages of disease progression (Kehagia, Barker, & Robbins, 2010).

Traditionally the most common communication disorder reported in PD is dysarthria of the hypokinetic type. The clinical speech language pathologist is usually called in to evaluate the motor speech disorder in PD. However, recent research reports are beginning to explore the language disorders in this population as well (Auclair-Ouellet, Lieberman, & Monchi, 2017; Smith & Caplan, 2018).

Even though there are no official data about the prevalence of PD in Greece, it is estimated that 20,000 individuals with PD are currently living in Greece. A very limited number of studies have explored the nature of linguistic deficits in Greek speaking patients with PD (Terzi, Papapetropoulos, & Kouvelas, 2005). This emphasizes the need for further research on the nature of the linguistic-cognitive deficits in native Greek-speaking individuals with PD.

The main body of the available research data regarding the linguistic deficits in PD has mainly been derived from studies in English. This means that fewer research studies have been carried out in other languages. Research from other languages so far on the linguistic characteristics of individuals with PD includes French (Péran et al., 2009), Spanish (Bocanegra et al., 2015), Persian (Johari et al., 2019), Italian (Cotteli et al., 2007) and Dutch (Colman et al., 2009). This enormous gap in the literature offers additional opportunities to advance the evidential and clinical foundations in exploring further the linguistic profile of patients with PD in additional languages. Even though the linguistic deficits are well established in PD and studied in English and to some extent in other languages, these findings are difficult to generalize in other languages that are understudied. The question that needs to be answered is whether the specific linguistic characteristic of each language (e.g., Greek language) affects the linguistic performance of individuals with PD.

Even though there are no official reports, it is estimated that 20,000 individuals with PD currently reside in Greece. A very limited number of studies have explored the nature of linguistic deficits in Greek speaking individuals with PD (Natsopoulos et al., 1991,1992;Terzi, Papapetropoulos, & Kouvelas, 2005). This emphasizes the need for further research in this specific population in Greece. The present study aims to fill this gap in the literature.

1. Organization of the thesis chapters

Chapter 2 Pathophysiology and Clinical characteristics of Parkinson Disease: this chapter provides an overview around the pathophysiology of PD, the presentation of the Braak stages, the anatomy of the frontal-striatum as well as a description of its role in cognition, the clinical characteristics, and the clinical scales that measure the severity of PD motor symptoms.

Chapter 3 Cognitive deficits in PD: this chapter presents the literature review on cognitive deficits in the early stages of disease as well as the clinical characteristics of Parkinson's Dementia. Also, the deficits in the domains of executive functions and verbal fluency are presented.

Chapter 4 Language disorders in PD: this chapter provides an overview of the most common linguistic deficits in the domains of single word processing, sentence processing, and metaphor processing.

Chapter 5 Research aims: this chapter includes the aims of the present study and provides a description of the main grammatical and morphological features of Modern Greek.

Chapter 6 Methodology: this chapter describes the study participants, the inclusion/exclusion criteria, materials, and methods used to carry out the study.

Chapter 7 Results: this chapter contains the statistical analysis that were carried out and the types of statistical analyses performed on the data.

Chapter 8 Discussion: this chapter elaborates on the study findings regarding cognitive functions, verb/noun processing subtests and sentence repetition test and test of

metaphor processing. The results are discussed in the light of current theories of word production and sentence processing.

Chapter 9 Clinical implications: this chapter contains an overall summary of the key findings of the study as well as the clinical implications and future research directions.

Chapter 2: Pathophysiology and clinical characteristics of Parkinson's disease

2.1 Introduction

This chapter is devoted to the pathophysiology as well as the clinical symptoms of Parkinson's disease (PD). Structurally, it consists of the presentation of the motor and non-motor symptoms of the disease, the anatomy of basal ganglia (BG) and the analysis of the structures of the fronto-striatal circuitry. This will provide the reader with the necessary information about the main clinical motor features of PD.

2.2 Clinical Characteristics

PD is a progressive neurodegenerative disease that affects 1% of the general population greater than 60 years of age (Tysnesn & Storstein, 2017). It is the most frequent neurodegenerative disease after Alzheimer's Disease (Aarsland et al., 2021).

The physician James Parkinson described Parkinson's Disease 200 years ago in his essay *The Shaking Palsy* in 1817 (Parkinson, 2002). Motor characteristics of PD include bradykinesia, rigidity, resting tremor and postural instability (Armstrong & Okun, 2020; Balestrino & Schapira, 2020). The main cause of PD is linked to dysfunction of the cortico-basal ganglia circuitries (Rodriguez-Oroz et al., 2009) (see table 2.1). The main pathological symptom of Parkinson's disease is the degeneration of neuromelanin-containing neurons in the pars compacta of the substantia nigra, which causes degeneration of the striatum (Logishetty & Chaudhuri, 2009).

PD is caused by loss of dopaminergic neurons in the substantia nigra (Armstrong & Okun, 2020; Bartels & Leenders, 2009; Davie, 2008). Although it was initially considered a "pure" motor disorder it is now well accepted that PD is characterized by both motor and non-motor symptoms (NMS) (Jankovic, 2008; Logishetty & Chaudhuri, 2009). PD is now considered a multifaceted disease characterized by large clinical heterogeneity (Amstrong & Okun, 2020; Balestino & Schapira, 2020; Braak, Tredici, Rub, de Vos, Steur & Braak, 2003; Kalia & Lang, 2015). It involves disruption of multiple brain areas including damage to the cortico-basal ganglia circuits (Rodriguez-Oroz et al., 2009; Kalia & Lang, 2015). It is important to mention that the Motor Disorder Society (MDS) has recognized the critical role of the non-motor symptoms in the process of diagnosis of PD (Postuma et al., 2015). The clinical neurologic examination is

still essential for the confirmation of the diagnosis of PD considering all the clinical symptoms (Davies, 2008).

Table 2.1: Definitions of the motor symptoms in PD

Motor symptom	Definition
Bradykinesia	The movements are slow and progressively smaller (hypokinesia) during multiple repetition of motor tasks such as tapping the index finger and thumb, opening, and closing the fist.
Rigidity	Involuntary, velocity-independent resistance to passive movement of a joint (e.g., elbow, wrist) by an examiner, with or without a cogwheel phenomenon.
Rest tremor	4- to 6-Hz tremor in a fully resting limb, which temporarily disappears when the limb is held outstretched and then returns(re-emergent tremor) and is not present during movement
Postural instability	The individual presents difficulty to walk or stand because of balance deficits.

(Armstrong & Okun, 2020; Logishetty & Chaudhuri, 2009)

2.2.1 Non-motor characteristics of PD

Schapira, Chaudhuri, & Jenner (2017), described the non-motor symptoms (NMS) that occur throughout the disease progression. Below is a schematic representation of the course of NMS

in PD.

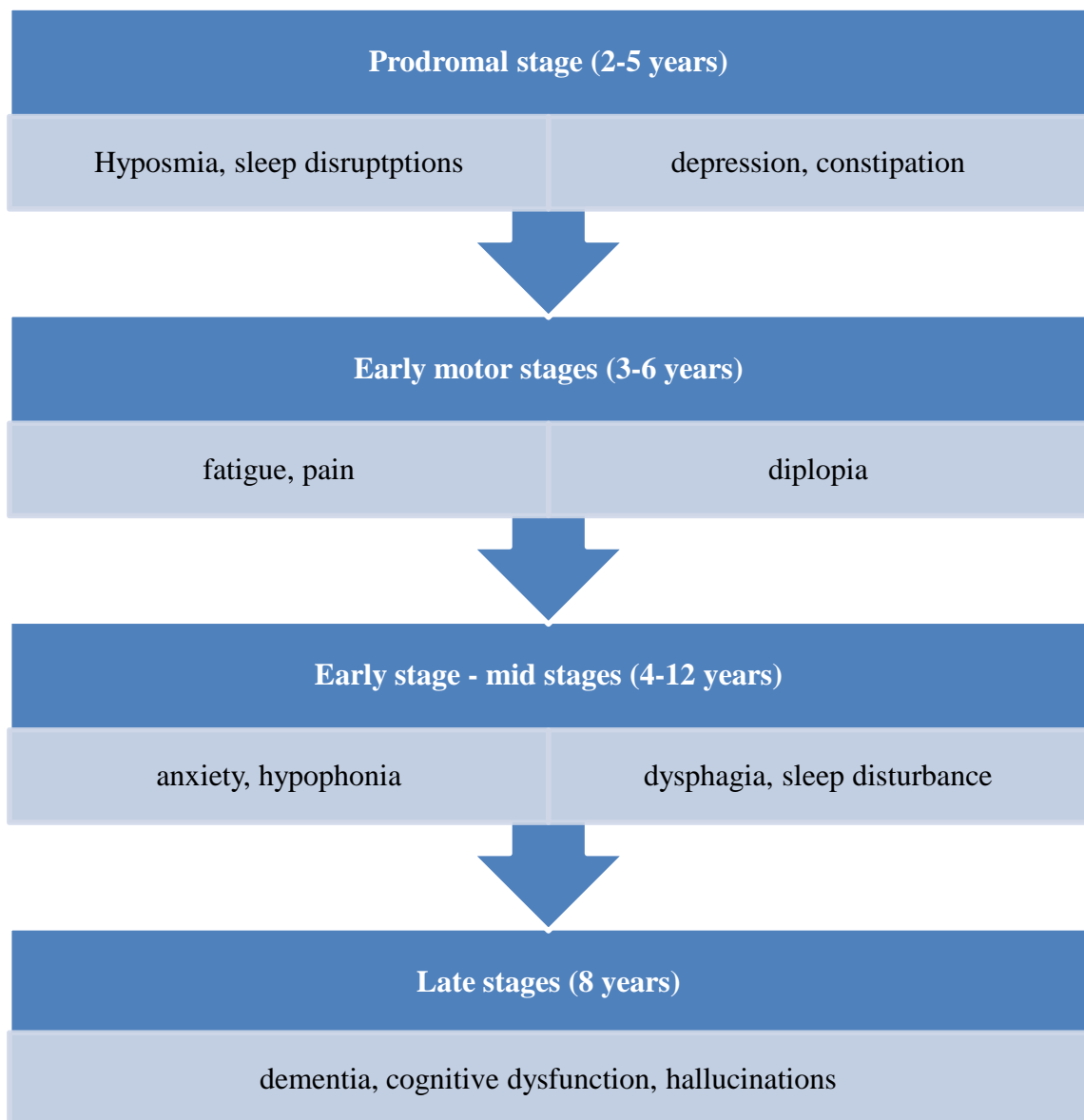


Figure 2.1: Schematic representation of the course of non-motor symptoms that occur throughout the course of PD

NMS includes olfactory deficits, visual disturbances, psychiatric disorders such as anxiety and depression (see table 2.2). Also cognitive decline and dementia may occur (Aarsland et al., 2017; Baiano, Barone, Trojano, & Santangelo, 2019; Halliday, Hely, Reid, & Adena, 2008). Importantly enough these symptoms may be present for a considerable period of time prior to the official diagnosis (Schapira et al., 2017).

Figure 2.1 depicts the course of how the non-motor symptoms develop over the course of the disease as well as the development of motor symptoms. NMS may occur prior to the clinical diagnosis.

Table 2.2: Definitions of the major non-motor symptoms of PD

Non-motor symptom	Definition
Olfactory loss	Decreased or absent sense of smell (hyposmia).
Sleep dysfunction	Rapid eye movement, sleep behavior disorder, daytime sleepiness, sleep-maintenance insomnia.
Autonomic dysfunction	Constipation, delayed gastric emptying, urinary disturbances, erectile dysfunction, orthostatic hypotension, blood pressure variability.
Psychiatric disorders	Depression, anxiety, apathy, psychosis.
Cognitive impairment	Mild cognitive impairment, dementia
Other disorders	Fatigue, voice disorders (hypophonia), motor speech disorders (hypokinetic dysarthria),swallowing disorders.

(Amstrong & Okun, 2020;Balestrino & Schapira, 2020)

2.3 Clinical diagnostic criteria

The MDS symptomatology defines the diagnostic criteria for PD. Clinical diagnosis requires the presence of the motor symptom of bradykinesia with rest tremor or rigidity. Also, the motor symptoms should improve with dopaminergic therapy (Postuma et al., 2015) (see table 2.3).

Table 2.3: Diagnostic symptoms of Parkinson Disease

Cardinal symptoms	<ul style="list-style-type: none"> • Bradykinesia • Postural instability • Rigidity • 4-6 Hz rest tremor
Supporting clinical symptoms (3 or more required for clinical)	<ul style="list-style-type: none"> • Tremors present only or more prominently with limbs at rest • Unilateral onset

diagnosis)	<ul style="list-style-type: none"> • Asymmetrical motor symptoms • Progressive disorder
Clinical symptoms indicative of other disorders	<ul style="list-style-type: none"> • Presence of encephalitis • Repeated strokes and brain injury • Hallucinations during the first 3 years of post-onset that are not related to medication • Severe postural instability in the initial stages of the disease • Dementia or major cognitive deficits occur earlier than motor disorders during the first year of clinical diagnosis • Supranuclear gaze palsy

(Armstrong & Okun, 2020; Balestrino & Schapira, 2020; Hughes, Daniel, Kilford, & Lees, 1992; Logishetty & Chaudhuri, 2009)

2.4 Anatomy of the Basal Ganglia

The basal ganglia (BG) consist of several subcortical structures that receive direct input from the cerebral cortex that send projections back to the cerebral cortex via the thalamus (Middleton & Strick, 2000). The BG contribute to both motor and non-motor functions such as motor learning, executive functions and behaviors, and emotions (Middleton & Strick, 2000; Lanciego, Luquin, & Obeso, 2012). It is now well established that damage of the BG generates cognitive and behavioral disorders in addition to motor disorders (Tremblay, Worbe, Thobois, Sgambato-Faure, & Féger, 2015).

The BG consists of several anatomical structures. Anatomical structures include the putamen, the caudate nucleus, the globus pallidus, the substantia nigra compact part and reticular part striatum subthalamic nucleus. The striatum consists of the caudate nucleus and the putamen and nucleus accumbens. The putamen and globus pallidus create together the lentiform nucleus.

The BG are organized into three circuits (a) motor; (b) associative, and (c) limbic/emotional based on how they function in association with their cortical projection areas and the engagement of these regions. The motor circuit includes the cortical areas of the supplementary motor area, premotor cortex, motor cortex and somatosensory cortex. These regions are connected to the putamen. The putamen in turn

projects to specific portions of the globus pallidus externa, interna and substantia nigra pars reticularis. The globus pallidus connects to the ventrolateral, ventral anterior and centromedian nuclei of the thalamus which projects back to the motor cortex (Gil-Robles, Gatignol, Capelle, Mitchell, & Duffau, 2005).

Both the striatum (that consists of the caudate and the putamen) and the subthalamic nucleus are the input anatomical structures of the basal ganglia. They receive information from several cortical and subcortical areas. The internal segment of the globus pallidus and the substantia nigra pars reticulata are the main output structures from the basal ganglia. The basal ganglia are connected to both motor brain regions (the motor cortex, supplementary motor cortex, premotor cortex, cingulate motor area) as well as to several non-motor brain regions (Leh, Ptito, Chakravarty, & Strafella, 2007).

2.5 Neuropathology of PD

Braak et al., (2003) proposed a model of six consecutive stages of the progression of neurodegeneration in PD. This model has been influential in further understanding and describing the course of the advancement of neuropathology in PD. According to this model, neurodegeneration first begins in the medulla and the olfactory bulb and this is considered the two initial stages (1st and 2nd). This neurodegeneration results in the non-motor symptoms such as rapid eye movement, sleep disorders and decreased smell. During the next two stages (3rd and 4th), the neuropathological changes appear to occur in the substantia nigra pars compacta and other midbrain and basal forebrain structures. The basic motor symptoms of PD occur during these two stages. Also, the clinical diagnosis of PD can be made at this stage. After these two stages, the neurodegeneration extends to several cortical brain areas. During the 5th stage, neural disruptions extend to the neo-cortex and the prefrontal neo-cortex. In the final stage (stage 6), mild damage is evident in the primary sensory and the motor cerebral areas.

2.6 Frontostriatal circuits

The cognitive dysfunction associated with PD is commonly attributed to damage in the fronto-striatal system (Kehagia, Barker, & Robbins, 2010; Lewis, Dove, Robbins, Barker, & Owen, 2003; Owen, 2004; Sawamoto et al., 2008). Damage to this specific neural circuitry produces several neurological and behavioral disorders (Tekin & Cummings, 2002; Tremblay et al., 2015). Recent clinical evidence proposes that the

fronto-striatal system involves in language processing as it is evidenced in language disorders in PD (Birba et al., 2017; Cardona et al., 2013; Murdoch, 2001). The frontal striatum system that is disrupted in PD, plays a critical role in language processing (Birba et al., 2016; Cardina et al., 2013). It is well known that cerebral atrophy may be detectable in the fronto-striatal areas as well as in the frontal lobe (Lee et al., 2014) and in the prefrontal regions (Biundo et al., 2011). BG with several frontal areas contribute to the ability of planning and as well as to goal directed behaviors (Haber, 2016).

The fronto-striatal circuits consist of several neuroanatomical connections between cortical areas mainly in frontal cortex and several subcortical regions (see fig.2.5). Anatomically the fronto-striatal circuits include the striatum (that consists of the caudate nucleus, the putamen, and the nucleus accumbens) that receives input from cerebral motor areas and frontal regions. These connections between the cerebral areas and striatal structures comprise three distinct circuits that regulate motor and non-motor functions (Alexander, DeLong, & Strick, 1986; Tekin & Cummings, 2002).

The dorsolateral prefrontal circuit contributes to executive functions. It includes the Brodmann's areas 9 and 10 on the anterior frontal lobe and the dorsolateral head of the caudate nucleus. Neurons from this region project to the lateral part of the mediodorsal globus pallidus interna and rostro lateral substantia nigra pars reticulata as the direct pathway. The fibers from the basal ganglia project to parvocellular portions of the ventral anterior and mediodorsal thalamus. The mediodorsal thalamus sends fibers back to the circuit origin in the dorsolateral prefrontal cortex (Tekin & Cummings, 2002).

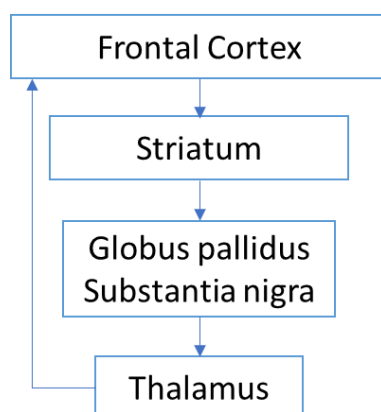


Figure 2.5: Frontal-subcortical networks

(adapted from Tekin & Cumming, 2002)

The frontal-subcortical circuits start from the prefrontal cortex and it is connected to the striatum (caudate, putamen, ventral striatum), to the globus pallidus and substantia nigra with the thalamus as the final structures. This circuit is connected back to the frontal cortex where each circuit forms a closed loop. Several connections with other cortical and subcortical areas are associated with each of these circuits (Tekin & Cumming, 2002).

The executive cortico-striatal loop begins from the cortical regions of the dorsolateral prefrontal and posterior parietal circuits and it is connected to the striatal areas, caudate head and the output structures of the basal ganglia, globus pallidus, the internal part of the substantia nigra pars reticulata and the thalamus (Tekin & Cumming, 2002).

The fronto-striatal system is responsible for controlling several higher-level cognitive abilities. These functions include executive functions such as problem-solving as well as automatic processing functions such as the ability to select the appropriate behavior that is related to a specific stimulus in order to complete a routine or familiar situation, referred to as automatic processing (Koziol & Budding, 2009).

According to Koziol and Budding (2009), the main cognitive functions of the frontal-striatal system are as follows:

- (a) Higher-order control ability to evaluate and analyze a new problem and to generate the appropriate solutions;
- (b) The ability to automatically generate appropriate solutions to a new problem;

The damage in the frontal-striatal circuits that is associated with PD disrupts both motor functions as well as higher level cognitive abilities (Birba et al., 2017). Overall, the higher cognitive functions attributed to the BG are the following: a) the control of attention; b) the control of working memory functions; c) the control of the speed of information processing (Kotz, Schwartz, & Schmidt-Kassow, 2009). Also, the BG are involved for sequence and category learning as well as in implicit and explicit learning (Seger, 2006). In addition to non-linguistic-cognitive deficits, the BG disruption and specifically the cortico-striatal damage generates mild dysfunction in complex language skills such as grammatical/syntactic processing (Copland, Brownsett, Iyer, & Angwin, 2021).

2.7 Clinical Scales for PD

In clinical practice, the severity of the motor symptoms as well as the stage of disease progression in PD can be determined by the administration of two common clinical assessment scales. These are (a) the Hoehn and Yahr (H&Y) Scale (Hoehn & Yahr, 1967) and (b) the Unified Parkinson's Disease Rating Scale (UPDRS) (Goetz et al., 2008). Below the description of these two scales are provided.

2.7.1 Hoehn and Yarn Scale

According to the H&Y scale the course of the disease consists of five distinguished clinical stages depending on the severity of the motor symptoms. It starts with the initial stage where the patient does not present any symptoms and signs of pathology and it ends in the final stage where the patient is wheelchair bound (see figure 2.6).

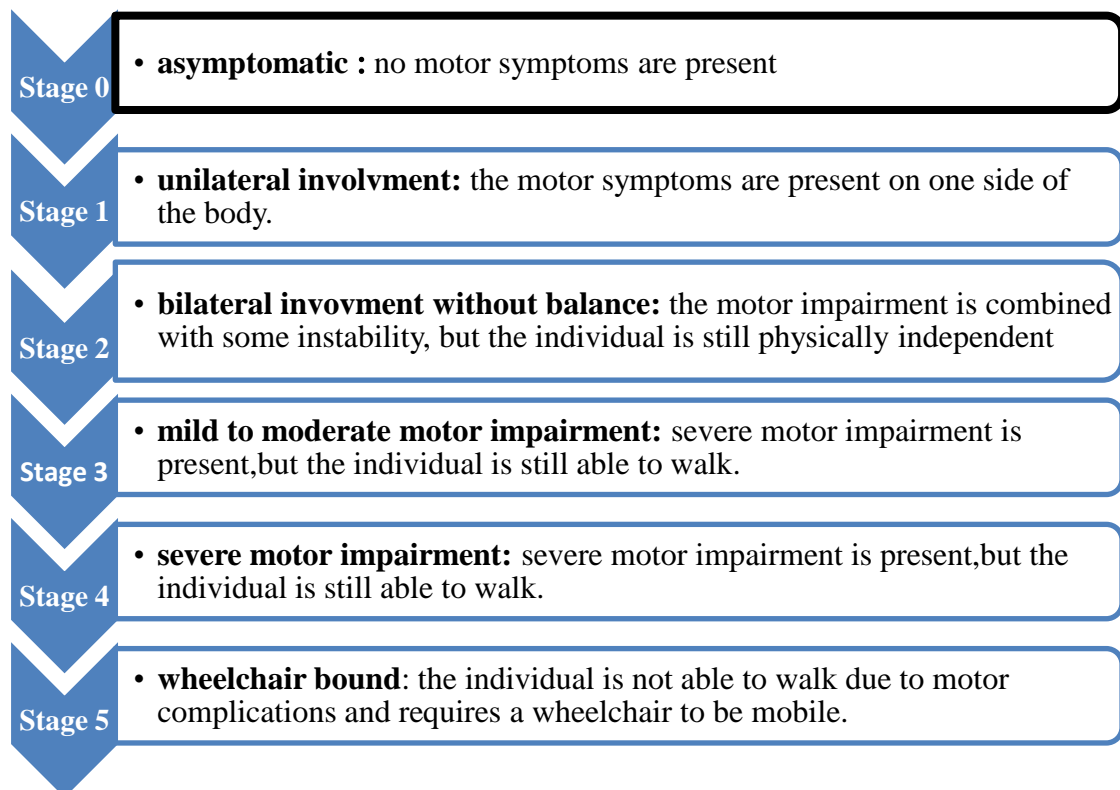


Figure 2.6: Hoehn and Yarn Scale

2.7.2 The Unified Parkinson's disease Rating Scale (UPDRS)

This scale evaluates the presence and severity of the motor and non-motor symptoms of PD and how these symptoms affect the person's ability to perform everyday activities (Goetz et al., 2008). It includes four parts as follows:

Part I: Non-motor Experiences of Daily Living;

Part II: Motor Experiences of Daily Living;

Part III: Motor Examination;

Part IV: Motor Complications.

Specifically, the motor examination includes 18 items that evaluate different aspects of motor disability such as speech, facial expression, rigidity, finger tapping, hand movements, pronation-supination movements of hands, toe tapping, leg ability, arising from chair, gait, freezing of gait, postural stability, posture, global spontaneity of movement, postural tremors of the hands, kinetic tremor of the hands, rest tremor amplitude, constancy of rest tremor (see figure 2.7). Each item is scored from 0 that represents the absence of motor symptoms to 4 that represents severe motor deficits. The maximum score is 72 and represents the highest severity of motor symptoms. The higher score represents higher motor disability.

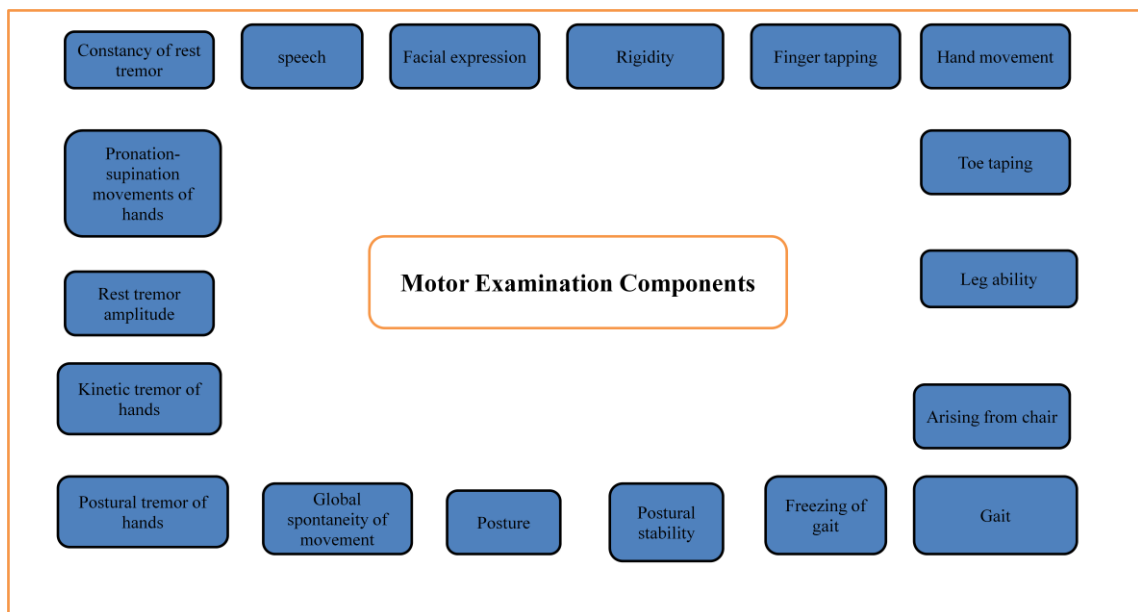


Figure 2.7: The Motor Examination components of the Unified Parkinson's Disease Rating Scale

Summary

In this chapter, the main clinical characteristics as well as the neuroanatomical basis of PD were described. In the following chapter, I will present an overview of the cognitive impairment related to PD.

Chapter 3: Cognitive deficits in PD

3.1 Introduction

The preceding chapter discussed the clinical picture of PD as well as its main underlying neuropathology. In this chapter, the clinical evidence regarding the cognitive disorders in PD is discussed. As PD is characterized by motor and non-motor symptoms, cognitive deficits are one of the non-motor symptoms that frequently arises early in the course of the disease. In addition, recent studies emphasize the role of the identification of cognitive deficits in the earliest stages of the disease and sometimes even in the prodromal stages. Moreover, in relation to the present study, a considerable body of research exploring the language disorders in PD, propose that the linguistic deficits seen in the early stages of PD are frequently attributed to non-linguistic cognitive impairment in different domains of cognition. To acquire a better understanding of the nature of the language disorders in PD, the analysis of the neurocognitive profile of individuals with PD must be considered.

3.2 Cognitive functions in PD

In recent years the clinical and research interest regarding PD has focused on exploring the nature of the cognitive deficits in the early stages of the disease (Aarsland et al., 2021). Cognitive deficits are now considered a common NMS of PD. The spectrum of cognitive deficits may range from normal cognitive abilities in the very early stages to severe cognitive deficits and dementia in the late stages of the disease (Aarsland et al., 2017; Dujardin et al., 2013, 2015; Kehagia, Barker, & Robbins, 2010). Also, one common clinical characteristic of cognitive deficits in PD is their great heterogeneity (Kehagia et al., 2010).

The cognitive deficits in PD have a negative impact on the person's quality of life (Klepac, Trkulja, Relja, & Babic, 2008) and are often underestimated in clinical practice due to the fact that they are often mild in severity (Barone, Aarsland, Burn, & Emre, 2011). The focus of recent clinical research on PD has shifted from the clinical characteristics of the dementia symptoms in advanced stages, to the cognitive decline in the early stages of the disease (Weintraub, Tröster, Marras, & Stebbins, 2018).

The cognitive abilities of patients with PD are broadly dichotomized into two major clinical stages (see figure 3.1). The first stage includes the initial stages of PD during

the time of the initial medical diagnosis where the individual may present intact or mildly impaired cognitive abilities. Recent clinical studies estimate that cognitive decline appears in 25% to 40% of individuals with PD during the early stages of the disease (Baiano et al., 2019; Weintraub et al., 2018). The second stage includes the later stages of the disease where neurodegeneration has significantly progressed so that major cognitive deficits occur and represent the clinical characteristics of dementia. It is estimated that 80% of the individuals with PD will develop dementia in the late stages of the disease (Reid, Hely, Morris, Loy, & Halliday, 2011). In the last decade the clinical and research interest in cognitive deficits, have focused on the initial stages of PD (Rodriguez-Oroz et al., 2009; Weintraub et al., 2018). In the current clinical research, several studies have claimed that the cognitive decline in PD is mainly attributed to dysfunction of the fronto-striatal circuit (Dubois & Pillon, 1997; Lewis, Dove, Robbins, Barker, & Owens, 2003; Owens, 2004).

3.2 Cognitive deficits in early stages

A plethora of studies have documented the presence of cognitive deficits in the early stages of the disease (Dubois et al., 2007; Elgh et al., 2009; Muslimović, Post, Speelman, & Schmand, 2005; Pfeiffer, Løkkegaard, Zoetmulder, Friberg, & Werdelin, 2014; Williams-Gray et al., 2007). Cognitive decline may affect all cognitive domains to different degrees (Curtis, Masellis, Davidson & Heather, 2019; Davis & Racette, 2016). However, the most frequently affected cognitive domains in the early stages of the disease are attention, executive functions, and memory (Elgh et al., 2009; Muslimovic et al., 2005).

There is an increased interest in cognitive changes that take place during the prodromal stages of PD where the clinical motor symptoms are not severe enough to lead to a medical diagnosis. Based on the current research evidence the deficits of executive functions and memory are the most frequently affected cognitive domains during these preliminary stages of the disease (Fengler et al., 2017).

Evidence to support the above finding comes from data from several clinical studies exploring the cognitive profile of large cohorts of non-demented individuals with PD. These findings will be presented in brief below.

In a longitudinal study, Pigott et al. (2015) explored the course of cognitive abilities in a group of one hundred and forty-one (n=141) newly diagnosed individuals with PD. All

participants had normal cognitive skills at the time of the initial medical diagnosis. During the progression of the disease, 8.5% of the participants presented cognitive deficits during the first year. This percentage progressively increased to 21.3% during the second year, 30.4% third year and 39.1% during the fourth year. Interestingly, 47.7% of these patients presented cognitive deficits in the sixth year-post initial diagnosis. The findings reveal that cognitive impairment may occur during all the stages of the course of the disease.

Dujardin et al. (2015) used a five-cluster model to describe the possible cognitive phenotypes identified in a group of one hundred and fifty-six (n=156) individuals with PD. According to the findings, five cognitive subgroups were identified in this sample. One subgroup consisted of participants with intact cognitive abilities and high levels of performance in all cognitive domains (25.64%). The second subgroup of participants were identified with intact cognitive skills but slightly slower processing speed than those in the first group (26.92%). The third subgroup of participants was mainly characterized by the presence of executive dysfunction (37.18%). The fourth subgroup consisted of participants with severe deficits in all cognitive domains, particularly executive functions (3.20%). The fifth subgroup had severe cognitive deficits in overall cognitive functioning, specifically in the domains of working memory and in verbal episodic memory (7.05%). These findings revealed that the cognitive deficits in PD are not a unitary entity but heterogeneous one characterized by wide variability.

In a more recent study, Alonso-Recio, Martín-Plasencia, Ruiz, and Serrano (2018), described the cognitive profile of seventy one (n=71) participants with PD. The findings resulted in four subgroups, as follows: (a) a subgroup that exhibited deficits in executive functions (32.4%); (b) a subgroup that exhibited memory deficits and executive dysfunction (28.2%); (c) a subgroup that exhibited memory impairment only (23.9%); and (d) a subgroup with normal cognitive function (15.5%).

Considering the results from the above studies it can be concluded that the course of cognitive decline in PD is non-linear, and that cognitive deficits are characterized by significant clinical heterogeneity.

3.2.1 Mild Cognitive Impairment in Parkinson's disease (MCI-PD)

The concept of Mild Cognitive Impairment (MCI) related to PD has been introduced in PD and has offered new insights into the pathophysiology of cognitive deficits in this

group of patients. It is estimated that around 40% of individuals with PD develop MCI in the early stages of the disease (Baiano et al., 2019; Litvan et al., 2012). MCI is considered a transitional stage between normal cognition and major cognitive deficits and dementia. It is characterized by a slowly progressive cognitive decline that may affect one or more cognitive domains but preserved behavior and activities of daily living. During the diagnostic process the cognitive impairment may be reported by either the patient or other informant, or observed by the clinician (Litvan et al., 2012). Other causes that may cause cognitive decline (e.g., delirium, stroke, major depression, metabolic abnormalities, adverse effects of medication, or head trauma) must be excluded. Also, depending on the domains that are impaired, PD-MCI is classified into two main subtypes: (a) Single-domain: deficits are present in a single cognitive domain while other domains are within normal limits; (b) Multiple-domain: deficits are present in at least two cognitive domains (Litvan et al., 2012).

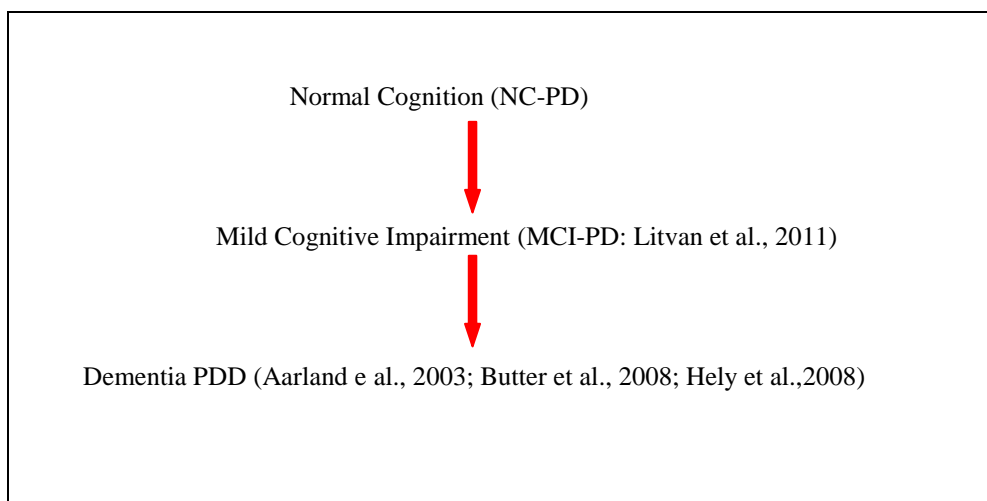


Figure 3.1: Three distinguished neurocognitive stages in PD progression

3.2.2 Dementia in Parkinson's disease

Dementia is very frequent in the late stages of the disease. It is estimated that 83% of individuals in the advanced stages of PD will develop dementia should they survive twenty years post diagnosis (Halliday et al., 2008). Emre et al. (2007) were the first to propose the diagnostic criteria for dementia in PD. Accordingly, the deficits must be present in at least two of the four cognitive domains. The most frequent deficits that occur in each domain are:

- (a) *Deficits in attention*: difficulty in spontaneous and focused attention.
- (b) *Deficits in executive functions*: difficulty in planning, conceptualization, initiation, rule finding, set shifting, mental slowness.
- (c) *Deficits in memory*: difficulty in recalling recent information and learning new information
- (d) *Deficits in visuo-spatial functions*: difficulty with visuo-spatial orientation, perception, or construction.

With regards to language abilities, word retrieval and complex sentence processing deficits may also be present.

Of special interest for the diagnosis of dementia in PD is the presence of a negative impact of cognitive decline on normal everyday functioning.

3.3 Executive **Dysfunction in PD**

Executive functions (EFs) are a number of top-down control cognitive functions that include working memory/updating, inhibitory control, cognitive flexibility/attentional shifting, planning, reasoning, and problem solving (Cristofori et al., 2019; Diamond, 2013; Stuss, 2011). EFs are supported by a widespread neural network that includes both cortical frontal and parietal regions as well as subcortical structures (Ye & Zhou, 2009).

Table 3.1: Definitions for each component of executive functions.

Ability	Description
Working memory	The ability to maintain the required information while working with it (e.g., investigating how the information are related, activation of the required information during problem solving).
Self-control	The ability to inhibit the activation of irrelevant information and inappropriate behaviors.
Cognitive flexibility	The ability to utilize alternative solutions for a specific problem, be able to adjust to task demands, follow new rules, or set priorities (as in ability to switch between different tasks)
Inhibition (<i>inhibitory control</i>)	The ability to control attention, behavior, thoughts, and emotions to override a strong internal or external lure

Executive control	It includes the cognitive processes that control the cognitive functions in sensory, memory and motor systems as internal goals. Executive control includes two basic mechanisms, that of conflict monitoring and conflict resolution.
Set shifting	The ability to switch rapidly between two or more different tasks

(Diamond, 2013; Ye & Zhou, 2009)

The cognitive deficits in the domain of executive functions are now considered the most common symptom in the early stages of PD as indicative of a fronto-striatal syndrome. This is suggested to be the core clinical characteristic of the cognitive profile of non-demented patients with PD (Curtis et al., 2019; Dirnberger & Jahanshahi, 2013; Kehagia et al., 2010; Kudlicka, Clare, & Hindle, 2011; Rodríguez-Ferreiro, Cuetos, Herrera, Menéndez, & Ribacoba, 2010). Executive deficits in the early stages of PD are frequently associated with the disruption of the fronto-striatum network (Lewis, Dove, Robbins, Barker, & Owen, 2003; Sawamoto et al., 2008). Executive dysfunction has frequently been observed, in the earliest stages of PD as well as in the late stages (Muslimovic et al., 2005). It is suggested that such specific executive deficits frequently underlie the language processing difficulty in PD (Colman, Koerts, Stowe, Leenders, & Bastiaanse, 2011; Colman et al., 2009; Grossman et al., 2002).

Executive deficits in individuals with PD are characterized by impairment in cognitive flexibility, planning ability, control of attention, set switching ability, inhibition, conflict resolution skills and learning (Dirnberger & Jahanshahi, 2013; Kehagia, Barker & Robbins, 2010).

3.4 Verbal fluency deficits

Verbal fluency skills require the coordination of several different cognitive processes. Specifically, they consist of the processes of lexical access, the ability to update and inhibit the responses, as well as lexical knowledge (Shao, Janse, Visser, & Meyer, 2014). Moreover, semantic fluency is associated with accurate word retrieval ability, whereas phonemic fluency is linked to vocabulary knowledge (Gordon et al., 2018). In

addition, the clinical evidence shows that phonemic fluency depends on the integrity of executive functions whereas semantic fluency is linked to retrieval of semantic representation (Gordon et al., 2018; Shao et al., 2014). Research findings suggest that phonemic fluency is related to the ability for word searching and depends on the integrity of the fronto-subcortical circuits (Robinson, Shallice, Bozzali, & Cipolotti, 2012).

The verbal fluency task consists of several cognitive processes. They include (1) immediate attention to initiate the generation of words; (2) the activation of lexical and semantic properties of the words that have to be selected; (3) the retrieval of the target word from the mental lexicon, and (4) the coordination of these different processes in order to produce the intended word (Ruff, Light, Parker, & Levin, 1997).

In this regard, Henry & Crawford (2004) conducted a meta-analytic study on the verbal fluency abilities in PD. They included two thousand six hundred and forty-four individuals with PD ($n=2,644$) from sixty-eight ($n=68$) studies. Overall, the individuals with PD showed greater deficits on semantic compared to phonemic fluency skills. The authors interpreted the results based on the nature of two tasks. Semantic fluency is more demanding as it requires additional cognitive resources for lexical access speed compared to phonemic fluency.

Obeso, Casabona, Bringas, Lazaro, & Jahanshahia (2012) assessed the verbal fluency skills in a sample of three hundred ($n=300$) non-demented participants with PD. The results revealed lower performance of the PD group for both verbal fluency tasks, phonemic and semantic, compared to healthy controls. In addition, overall, phonemic fluency was more impaired than semantic fluency (Obeso et al., 2012).

Clinical studies have explored the neural networks that result in verbal fluency deficits in the early stages of PD. Pereira, Junque, Ramirez-ruiz, & Bartre (2009) investigated the neural underpinnings of phonemic and semantic deficits in non-demented PD patients. The results showed that semantic fluency abilities in PD patients correlated with structural lesions in the inferior and middle frontal gyrus and in several neural areas in the temporal lobe. In a recent study, El-Nazer et al. (2019) claimed that phonemic fluency deficits in PD are correlated with greater pathological changes across frontal, temporal, and limbic regions. It can be concluded from the above results that verbal fluency deficits are correlated with damage to a widespread neural network with

some possibly overlapping brain areas but overall, the results highlight the hybrid character of both fluency tasks.

3.5 The Dual Syndrome Hypothesis

For what concerns the notion of clinical heterogeneity in PD, Kehagia, Barker, and Robbins (2012) proposed the Dual Syndrome Hypothesis that divides the individuals with PD into two clinical groups depending on the cerebral regions where the neural changes are observed. The first group presents deficits in the cognitive domain of executive functions especially in tasks of planning and working memory. This is mainly caused by the disruption of the fronto-striatal network and is described with the term "dysexecutive syndrome". The second group is characterized by deficits in visuospatial abilities and in semantic fluency. This is due to disruption of the posterior cortical regions and involvement of the temporal lobe.

3.6 The neural underpinnings of the cognitive impairment in PD

Recent neuroimaging data have generated several interesting findings regarding the neural underpinnings of cognitive impairment in PD. Cerebral atrophy occurs in the cortical and subcortical regions responsible for cognitive functions in the early stages of the disease (Mak et al., 2015; Tessa et al., 2014; Wilson, Niccolini, Pellicano, & Politis, 2019). Cognitive impairment is associated with widely distributed cortical atrophy at the time of the clinical diagnosis (Pereira et al., 2014). On the other hand, executive dysfunction in PD is specifically correlated with decreased volumes in fronto-striatal circuits (Filoteo, Reed, Litvan, & Harrington, 2014) as well as with disruption in frontal and parietal regions (Duncan, Firbank, O'Brien, & Burn, 2013). Most interestingly, individuals with PD with normal cognitive abilities present a greater degree of frontal cortical thinning compared to healthy controls with reduced volume at cortical and subcortical regions in non-demented PD (Mak et al., 2015).

3.7 Summary

The findings from published research presented in this chapter confirm that cognitive deficits frequently occur in the early stages of PD. The cognitive deficits are attributed to damage in fronto-striatal circuits because of neurodegeneration as part of the disease process. The nature of cognitive impairment is similar with that of frontal lobe lesions. Executive functions seem to be the most frequently affected cognitive domain in the

earliest stages of the disease. Overall, PD is characterized by great heterogeneity. Even though there has been great progress in advancing the clinical and theoretical knowledge about the nature of the cognitive impairment there is still a huge gap in our knowledge. This makes the prediction of the precise course of cognitive functioning abilities in individuals with PD difficult.

Chapter 4: Language disorders in Parkinson's disease

4.1 Introduction

In the previous chapter the nature of the cognitive deficits in PD was discussed. The aim of this chapter is to review the current evidence regarding the clinical characteristics of language disorders in PD. Language disorders are part of the NMS complex. An overview of language disorders specifically in the areas of (a) noun and verb retrieval; (b) sentence processing and (c) processing of idioms, will be highlighted.

4.2 Clinical characteristics of language disorders

PD is a neurodegenerative disease that has a negative impact on the communication ability of the person with PD (Miller, 2017; Schalling, Johansson, & Hartelius, 2018). Also, the communication disorder is a barrier to the opportunities people with PD must engage socially and as a consequence has a negative impact on quality of life (Miller, Nobler, Jones, & Burn, 2006). Regarding the language disorders, it has been documented that PD patients present deficits in different levels of lexical processing such as morphosyntactic processing deficits, lexical-semantic deficits, and high-level language processing impairments (Auclair-Ouellet, Lieberman, & Monchi, 2017; Altmann & Troche, 2011; Cardona et al., 2013; Murray, 2008; Pell & Monetta, 2008; Smith & Caplan, 2018).

Based on the findings from clinical studies, language functions are often reported to be the least affected domain compared to other non-linguistic cognitive abilities (e.g., working memory, executive functions, memory, and attention) concerning individuals in the early stages of PD. A recent report by Hoogland et al. (2018) analyzed cognitive-linguistic results from two thousand nine hundred and eight (n=2908) non-demented individuals with PD and concluded that language was the least affected domain in this group of patients compared to other non-linguistic cognitive functions (e.g., memory deficits, executive dysfunction). However, most studies referenced in the report assessed language skills by administering confrontation naming tasks that mainly included nouns. It is possible, that this type of assessment task was not suitable or linguistically demanding enough to detect language deficits especially if subtle. Considering the above points, the clinical evidence regarding the existence of language disorders in PD, is presented in the next section.

Pfeiffer et al. (2014) examined the cognitive abilities of eighty-three (n=83) individuals in the early stages of PD (1-5 years from diagnosis, H&Y \leq 3). Language functions were assessed on tests of noun retrieval (picture naming test, & verbal fluency). The results revealed that language ability was the least impaired domain (11%) compared to other non-linguistic cognitive functions such as executive functions and memory. The authors concluded that language skills were largely preserved in this group of early-stage PD individuals.

Similarly, Yarnall et al. (2014) investigated the cognitive abilities in two hundred (n=200) individuals with early stage PD. Language skills were evaluated using the naming (0-3) and sentence repetition (0-2) subsets of a standardized cognitive screening test, the Montreal Cognitive Assessment (MoCA). The results revealed that only 5% of participants with PD presented with language impairments. The authors suggested that naming skills are relatively preserved in the early stages of PD.

The results of these two studies suggests that the confrontational naming task of nouns is either the least affected linguistic function or the most preserved compared to other non-linguistic domains. Therefore, this was taken as an indication that language abilities are generally preserved in the early stages of PD. However, as it will be shown below, the data from other clinical studies concerning the naming abilities in PD suggest that this may not always be the case.

4.3 Language disorders in the early stages of PD

An emerging area of research is the study of language disorders in the early stages of the disease. It is now well known that the language disorders do occur in the early stages of PD. On the other hand, other studies have suggested the predictive role of linguistic deficits in informing the development of cognitive impairment and vice-versa (Copland et al., 2021).

There is also some evidence arguing that the linguistic difficulties may occur even in the preclinical stages of the disease (Cardona et al., 2013; Garcia et al., 2017). One study proposed that the syntactic deficits may occur earlier than the other linguistic and non-linguistic cognitive deficits over the course of the disease (Garcia et al., 2017). To this end, other evidence suggests that verb retrieval deficits may also serve as a clinical marker of cognitive impairment in the early stages of PD (Cardona et al., 2013). Studies have suggested that the language disorders in the early stages of the disease may reflect

a prognostic value for future development of severe cognitive deficits. Reid, Hely, Morris, Loy, & Halliday (2011) found that individuals with PD that present linguistic deficits specifically low vocabulary scores, in the early stages of the disease, are more likely to develop cognitive impairment in the advanced stages of the disease. In addition, naming deficits may be a prognostic variable for the probability of impairment in more than one of the non-cognitive linguistic domains (Hobson & Meara, 2015).

Also, language disorders may reduce the quality of everyday communication interaction. It has been suggested that caregivers are able to identify the language impairment specifically the comprehension difficulties before any other cognitive deficit occurs (Wolff & Benge, 2019). This latter study suggested that 30%–40% of individuals with PD had auditory comprehension deficits before they developed deficits in other cognitive domains.

4.4 Underlying cognitive deficits in linguistic deficits

The ability to communicate requires the interaction among linguistic and non-linguistic cognitive abilities. Cognitive-communication disorders are defined as deficits in all linguistic capacities such as listening, speaking, reading, writing, and the ability to participate in a conversation caused by the impairment in non-linguistic cognitive abilities such as memory skills, executive functions, attention skills and processing information (Macdonald, 2017).

An ongoing debate is around the origin of the linguistic deficits in PD. Previous research reports have supported that the language deficits in PD are not purely linguistic per se but they may be caused by the presence of impairments in other non-linguistic cognitive domains (Bastiaanse & Leenders, 2009; Moreau & Pinto, 2019). Specifically, it has been suggested that language deficits may be viewed either because of deficits of executive functions or related to decline in both linguistic and non-linguistic cognitive abilities (Moreau & Pinto, 2019). It is of major clinical significance to acknowledge that linguistic deficits are frequently underestimated in clinical practice (Moreau & Pinto, 2019). There is some research that has specifically explored the relationship between sentence processing and executive dysfunction. Executive functions play a critical role in sentence processing (Key-delyria & Altmann, 2016). Indeed, a number of clinical studies have proposed that the executive dysfunction contributes to language disorders in PD (Grossman et al., 2002; Lee, Grossman, Morris, Stern, & Hurtig, 2003).

It is worth noting that a common finding around sentence processing deficits in PD is that the individuals with PD have difficulty processing sentences with complex syntax such as non-canonical structures (e.g., object relative clauses). This can be explained by the complexity factor for these sentence types that require additional computational resources compared to simpler syntactical structures (e.g., subject-verb-object). Also, individuals with PD have difficulty utilizing the required strategies to process the sentence in a different or non-canonical order (Auclair-Ouellet et al., 2017).

4.5 Language and Cognition Dysfunction

A number of studies have investigated the possible link between the cognitive deficits and linguistic abilities in PD. Earlier on, Lewis, Fiona, Lapointe, Murdoch, & Chenery (1998) explored the language processing deficits in a group of twenty (n=20) non-demented English-speaking individuals with PD. They administered several high-level language production tasks. These tasks included several lexical processing tasks such as a naming test, a word test, a test of language competence and a word fluency test. In addition, different lexical tasks required the participants to provide synonyms and antonyms, to use specific words in grammatical sentences, to define words and to interpret metaphors. According to the results, the individuals with PD had worse performance on linguistic tasks that were linked to functions of the frontal lobe and required executive skills such as organization, planning, information processing, abstract thinking, and rule application. The authors claimed that overall language functions were preserved and that the observed language disorders were solely attributed to coexistence of deficits in non-linguistic cognitive domains and specifically to disruption of the frontal lobe.

In another study, Berg, Björnram, Hartelius, Laakso, & Johnels (2003) studied the high-level language processing skills in a group of forty (n=40) individuals with PD with normal cognitive abilities. Several lexical tasks were administered. These tasks included word processing such as providing word definitions, metaphor comprehension, sentence repetition and the ability to make inferences. According to the results, the ability to make inferences was the only task where a significant difference was demonstrated between the two groups. Also, the global cognitive ability of individuals with PD was correlated with linguistic deficits.

In his early work, Grossman and his colleagues (Grossman, Lee, Morris, Stern & Hurtig, 2002; Lee, Grossman, Morris, Stern, & Hurtig, 2003) offered several insights regarding the nature of sentence processing deficits in PD. These studies explored the link between the deficits in different cognitive domains and processing of complex sentences. In particular, comprehension deficits were attributed to slow speed of information processing and limited executive resources (Grossman et al., 2002).

Lee et al. (2003) explored whether executive functions contribute to the comprehension of syntactically complex sentences (object-relative center-embedded clauses, object-relative center embedded clauses). The researchers included several executive function measures such as category naming fluency, stroop test, trail making test and digit span test. The results revealed that the sentence comprehension deficits were associated with reduced cognitive resources related to attention and information processing speed.

Colman, Koerts, Stowe, Leenders, & Bastiaanse (2011) found that difficulty in comprehension of passive sentences was specifically correlated with executive dysfunction and in particular the deficits in set-switching ability. The authors interpreted this finding as a correlational relationship between linguistic and executive functions. Other studies have revealed a slower lexical activation during the processing of non-canonical sentences (Angwin, Chenery, Copland, Murdoch, & Silburn, 2007). This is related to slow speed of information processing. The presence of cognitive impairment is associated with deficits at the lexico-semantic level whereas the patients without cognitive deficits present a selective linguistic deficit (Bocanegra et al., 2017).

In summary, the sentence processing deficits in PD seem to be correlated with the dysfunction in executive functions (see table 4.1). This supports the concept that the linguistic deficits may be derived from concurrent cognitive impairment in non-linguistic cognitive domains giving the specific distinctive linguistic profile of PD.

Table 4.1: Key findings from studies reporting on language disorders in PD

Study	Participants	Tasks	Results
Lewis, Lapointe, Murdoch & Chenerey (1998)	20 PD 20HCs	To provide synonyms and antonyms, to use specific words into grammatical sentences, to define words and to interpret metaphors.	Language disorders were ascribed to deficits in non-linguistic cognitive functions related to executive functions. Lexical tasks of providing definitions and processing ambiguous sentences and metaphors more difficult in the PD group.

Berg et al.(2003)	30 PD 26 HCs	Repetition+recreating sentences, inferences, comprehension, definitions.	Reduced accuracy in making inferences.
Lee et al. (2003)	19 PD 31 HCs	Sentence comprehension/word detection.	Reduced executive resources for attention and processing speed contribute to deficits in sentence comprehension in PD.
Terzi et al. (2005)	27 PD, 27 HCs	Past-tense processing	No specific language deficit. Poor performance due to cognitive demands.
Colman et al.(2011)		Processing of passive sentences.	Set-switching were linked to the comprehension deficits of passive sentences.

4.6 Metaphor and idiomatic language processing deficits

Another domain that has attracted clinical interest is the processing of metaphors and idioms by individuals with PD. Non-literal language is defined as a series of words that in order to be processed one is required to process beyond the literal meaning of the sentence (Rapp & Wild, 2011). Non-literal language is more abstract and may use similes, metaphors, and personification to describe something.

In particular, metaphor processing requires more than the lexical and semantic processing of each lexical item of the sentence (Glucksberg, 2003; Rapp et al., 2004). Understanding the meaning of a metaphor is a complex and cognitively demanding task. It requires several high-level cognitive operations such as the ability to associate the different linguistic items of the sentence that are not connected (Rapp et al., 2004). Also, during the metaphor processing, the individual must keep the metaphoric sentence in working memory to complete several additional processes to extract the correct meaning. According to the Career of Metaphor Hypothesis (Bowdle & Gentner, 2005) metaphor processing includes several cognitive processes as follows: a) the lexical access of the words of the metaphor; b) the activation of the semantic information of the word of the sentence; c) the literal figurative elements of the word in semantic memory; and d) the switch between the different attributes (Bowdle & Gentner, 2005).

In addition to the above processes, another important cognitive function is the ability to suppress the irrelevant information, and at the same time, to enhance the metaphor-

relevant information (Gernsbacher, Keysar, Robertson, & Werner, 2001). The neural underpinnings of metaphor processing is associated with the integrity of the frontal lobe and specifically the left fronto-temporal cerebral areas that are activated during the metaphor process (Bohrn, Altmann, & Jacobs, 2012). Since metaphors and idioms are frequently used in our everyday communication activities, a body of research has explored how they are affected in different neuropathologies including PD.

Several studies have explored the processing of metaphors in individuals with PD (see table 4.2). In an early study, Berg et al. (2003) explored the comprehension skills of metaphors in a group of twenty-six (n=26) patients with PD. The individuals with PD had normal cognitive abilities and matched healthy controls. Several high-level language tasks were administered. Specifically, the authors utilized the linguistic tasks of word definition, metaphor comprehension, sentence repetition, and ability to make inferences. Regarding the task of metaphor comprehension, the participants were asked to provide the meaning of the metaphor with their own words of each one of the metaphors. The results revealed that the PD group had difficulty processing the metaphoric expressions.

In another study, Monetta & Pell (2007) examined metaphor comprehension in a group of individuals with PD and healthy controls. The participants were required to read a sentence and decide whether the sentence was meaningful or not. According to the results the PD participants had difficulty with this task and required more time to complete the task than the control group. Also, the results suggested that the metaphor comprehension difficulty was associated with reduced working memory ability and frontal lobe dysfunction.

Papagno, Mattavelli, Cattaneo, Romito, and Albanese (2013) conducted an interesting study. They explored the processing of literal and idiomatic sentences containing action verbs in a sample of fifteen individuals with PD. They administered three categories of sentences: a) fifty (n=50) literal sentences half plausible and half implausible; b) fifty (n=50) idiomatic ambiguous sentences half plausible and half implausible; c) fifty (n=50) sentences containing no action verbs. The measures were taken on reading time and plausibility for each sentence. The PD group performed faster and was more accurate on sentences with non-action verbs compared to idiomatic and literal

sentences. Taking everything into account the results from the above-mentioned studies, individuals with PD have difficulty processing metaphoric and idiomatic expressions.

Table 4.2: Key findings from reported studies on metaphor and idiomatic language processing

Study	Participants	Lexical Task	Results
Monetta & Pell (2007)	17 PD 17 HCs	Metaphor comprehension task	Reduced accuracy to process metaphors due to verbal working memory deficits.
Papagno et al. (2013)	15 PD 15 HC	Processing of idiomatic/literal sentences containing action verbs	Idiomatic/literal sentences were more difficult to process.

4.7 Neural underpinning of language deficits in PD

Several clinical studies have produced evidence supporting the specific role of BG in language processing. A recent study (Radanovic et al., 2017) reviewed the language disorders that are associated with vascular lesions in BG during the acute phase of recovery. This study found that 46.6% of the patients exhibited word finding difficulties, 30% exhibited comprehension difficulties and 26% exhibited repetition deficits. However, 39.4% of the individuals with vascular lesions did not present language impairment. Interesting enough was the finding that when the deficits persisted for longer than 6 months, the percentage of patients with word retrieval difficulties was increased to 56.4%. These findings indicate the important role of the BG in language processing. Regarding the specific neuroanatomical structures of BG, the striatum collaborates with frontal regions in order to contribute to linguistic functions (Chan, Ryn & Bever, 2013). Moreover the pre-SMA-basal ganglia circuitry has an active role in the processes of searching and selecting for the target lexical item in the mental lexicon (Bohsali, 2016). In addition, recent clinical evidence supports that the damage in fronto-subcortical neural networks that are commonly affected in movement disorders may contribute to the naming difficulty (Cotelli et al., 2018).

4.8 Action-related language processing deficits in PD

Naming deficits are common symptoms of PD and historically have been reported from very early on (Matison, Mayeux, Rosen, & Fahn, 1982). Individuals with PD report that word finding difficulties are one of the most frequent and frustrating communication impairments they suffer from (Schalling et al., 2018).

Several clinical studies have attempted to elucidate the specific nature of noun and verb retrieval deficits in non-demented individuals with PD (Bertella et al., 2002; Cotelli et al., 2007; Herrera, Rodríguez-Ferreiro, & Cuetos, 2012). The research findings propose that the individuals with PD present disproportional retrieval deficits in verb naming compared to noun naming. However, the word retrieval deficits are still underestimated in clinical studies. Several clinical studies have documented several cognitive and linguistic factors that may contribute to impaired verb production in PD patients (Cotelli, Manenti, & Brambilla, 2017; da Silva, Machado, Cravo, Parente, & Carthery-Goulart, 2014).

The rationale for exploring action-word processing is based on the common view that there is a functional interaction between the motor and language systems during lexical processing of action words (Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005). The experimental data suggest that the processing of action words activates both motor and pre-motor cerebral regions (Hauk, Johnsrude, & Pulvermüller, 2004). The motor system contributes to language processing (Ibáñez et al., 2013). Relevant to the association between the language and motor systems is the theory of embodied cognition. This theory supports that the processing of action-verbs involves the recruitment of neural networks responsible for the planning and execution of these actions such as the primary motor and the pre-motor cortex (Hauk et al., 2004; Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012). A frequent account for the action verb retrieval deficits in PD is based on the concept that the ability of planning and execution of movements shares the same neural circuitry (Hauk et al., 2004). Since PD generates motor disorders, due to this overlap between the two cerebral regions it is possible to result in verb deficits.

PD offers the appropriate framework to examine how the motor and language areas are related during the action word processing tasks and specifically how the motor disorders may affect the language processing in the case of a neurological impairment. Indeed,

current data claim that lexical and semantic processing of words with motor content may be influenced by the integrity of the motor system (Boulenger et al., 2008; Cotelli, Manenti, Brambilla, & Borroni, 2017).

4.8.1 Noun-verb processing differences

A great body of literature has explored the differences between nouns and verbs in several clinical populations with various neuropathologies (Cotelli et al., 2017; Kambanaros & Grohmann, 2015; Matzig, Druks, Masterson, & Vigliocco, 2009). A general difference between nouns and verbs is that nouns are words that represent objects whereas verbs are words that represent actions (Kemmerer, 2014; Spezzano & Radanovic, 2010). The conceptual representations for both grammatical categories in the mental lexicon include information about the semantic, syntactic, morphological, and phonological properties of the word. All this information needs to be retrieved during word production in order for the procedure to be successful (Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011). According to the existing literature, both grammatical classes, nouns and verbs, may be selectively damaged at different processing levels: at the phonological, orthographic, lexical, semantic or lexical-syntactic level (Crepaldi et al., 2011; Kambanaros & Grohmann, 2015; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011). Furthermore, differences between verbs and nouns concerns their neural underpinnings. The verb retrieval is mainly associated with the activation of frontal brain areas whereas noun retrieval is linked to activation of temporal and more posterior brain structures and circuits (Damasio & Tranel, 1993; Tranel, Kemmerer, Adolphs, Damasio, & Damasio, 2003; Vigliocco et al., 2011). Also, verbs are considered more cognitively demanding than nouns as they require more computational resources (Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011). Noun and verb retrieval deficits have been also documented in several clinical studies with a variety of neurodegenerative diseases. This impairment has been reported in the non-fluent variant of primary progressive aphasia (Karpathiou & Kambanaros, 2019) the behavioral variant of frontotemporal dementia and Parkinsonian syndromes such as corticobasal syndromes and progressive supranuclear palsy (Cotelli, Fatebenefratelli, & Calabria, 2006; Cotelli et al., 2017; Peterson et al., 2021).

4.8.2 Stages of confrontational naming

Confrontational naming combines different cognitive processes and according to psycholinguistic models consists of different stages (Gleichgerrcht, Fridriksson, & Bonilha, 2015; Levelt, Roelofs, & Meyer, 1999). Gleichgerrcht et al. (2015) described the clinical features of the naming deficits that may occur at each stage.

Stage I: the first stage of lexical processing that consists of visual processing and recognition of the target lexical item. The naming difficulty that may arise at this stage is due to the inability to highly recognize the target word.

Stage II: the second stage of the lexical processing includes the semantic processing of the target lexical item. The naming difficulty in this stage is related to the deficient semantic processing of the word. The clinical symptoms that manifest the naming deficits may be the production of semantic errors and circumlocutions. In addition, comprehension deficits at the single word level may also occur.

Stage III: the third stage of lexical processing includes the selection of the abstract representation of the target lexical item. The clinical symptoms that represent deficits in this stage are word finding difficulties characterized by the production of semantic paraphasias, phonemic paraphasias, and circumlocutions.

Stage IV: the fourth stage of lexical processing consists of the execution of the name of the target lexical item. The deficits that may arise at this stage are due to deficits in the retrieval process of the phonological representation of the target word. The output may be phonemic paraphasias, distorted words, and word retrieval hesitations.

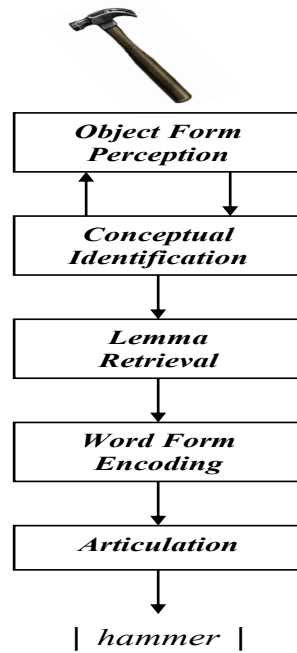


Figure 4.1: Lexical model of word production

Kambanaros (2003) (with permission from the author)

Different lexical models have been proposed to describe both single word production and sentence generation (Dell, 1986; Levelt, 1989).

Levelt (1989) suggested a model of word production named the *blueprint for the speaker* (see figure 4.2). This lexical model provides the theoretical basis for the naming disorders. According to this model, word production consists of four distinct stages:

- (a) *message generation*;
- (b) *grammatical encoding*;
- (c) *phonological encoding*;
- (d) *articulation*.

Each stage consists of three components: (a) *the conceptualizer*; (b) *the formulator*, and *the articulator*. Each component of the model operates independently and there is no interaction or cascading of activation between the components. Each of the three

processing components contains several procedures that make up the speaker's procedural knowledge. The procedures operate on the declarative knowledge that is stored in the speaker's mental lexicon.

The lexical retrieval process consists of two stages: a) *lemma selection* and b) *lexeme retrieval* (Levelt, 1989; Levelt, Roelofs & Meyer, 1999).

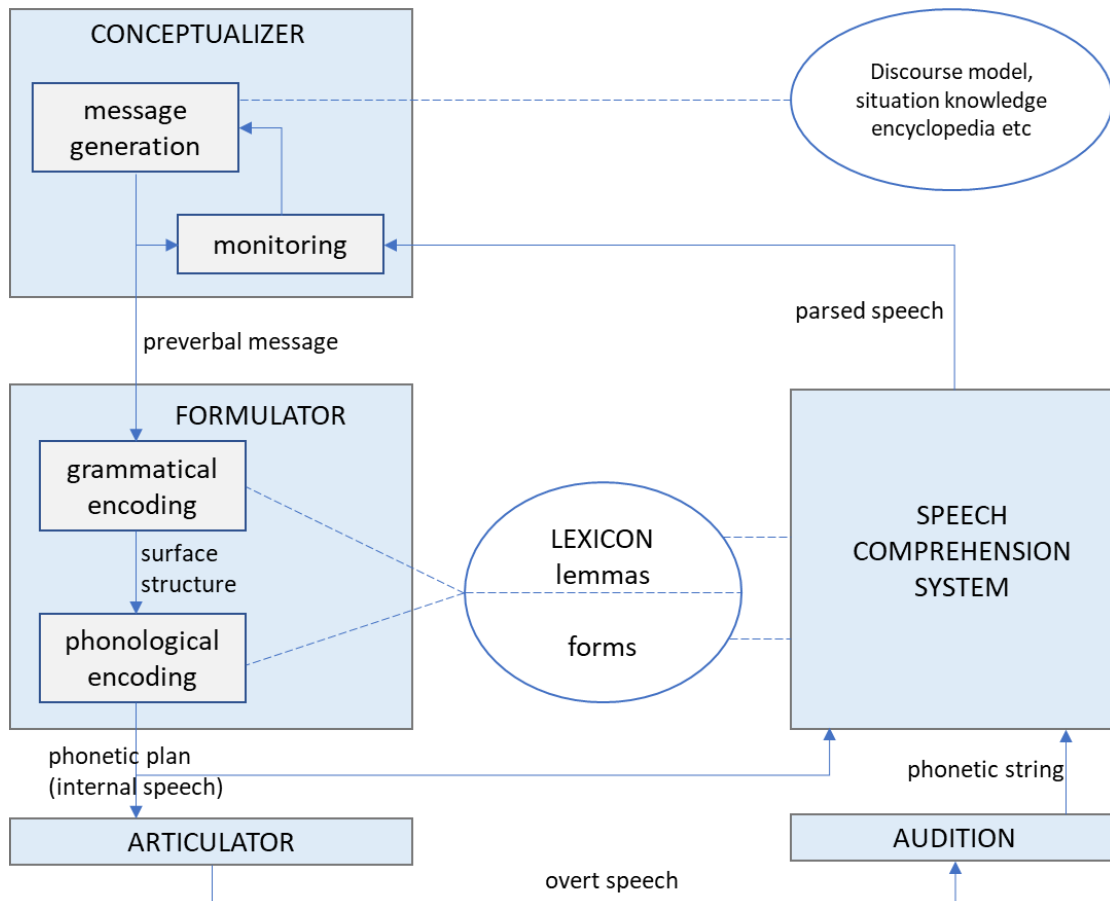


Figure 4.2: The Blueprint for the Speaker model of speech production

(adapted from Levelt, 1989)

Two basic elements of this model of word production are a) the lemma and b) the lexeme.

The lemma is an abstract, language-specific form of the intended word and includes information about the semantic and syntactic properties of the word (Levelt, 1989).

Lemma retrieval is conceptually driven (Levelt, 1989; Levelt, Roelofs & Meyer, 1999).

For example, during picture naming a speaker must name the pictured object/action (e.g., say “hammer” when presented with a pictured hammer).

The information in the picture (e.g., the noun-hammer) contains the *message concept that* needs to be verbalized (Levelt et al., 1999). The preverbal message is received by the *formulator contains the preverbal message*, the *grammatical encoder*, (a subcomponent of the formulator) as proposed by Levelt (1989).

The process of grammatical encoding requires both the semantic and syntactic features of the word. The process of naming an object (e.g., spoon), includes the activation of the *noun lemma* that contains grammatical information about the noun, such as plurality and gender. During the process of verb naming, the corresponding lemma is activated containing specific information about the verb grammatical properties (Levelt, 1989; Levelt et al., 1999). The lemma of both verbs and nouns contains information about the lexical-semantic and the grammatical properties of the word (Levelt, 1989).

At the second stage of word retrieval, the lexeme or word form corresponding to the selected lemma is phonologically specified. Lexemes contain information about the phonological representation of the target word such as number of syllables, prosodic features, and morphological information.

Levelt (1989) described four different occasions where the word retrieval may be impaired that is, a) during the access/retrieval of the semantic representation of the target word; b) during the process of retrieving the lemma; c) during the access of the morphological and the syntactical information of the word; d) during the process of access and retrieval of the phonological structure of the target word within the phonological output lexicon.

Also Dell (1986) proposed the spreading activation model for word and sentences production. According to this model, the process of retrieval of the key word will activate the simultaneous retrieval of all the semantically related words.

Evidence from previous studies proposes that verbs require more processing resources compared to nouns and that verb deficits documented specifically in movement disorders are attributed to the semantic deficits of action representation (Vigliocco, Vinson, Druks, Barber, & Cappa, 2011).

4.8.3 Noun-verb processing deficits in PD

Different accounts have been proposed for the interpretation of the deficits in verb retrieval ability in individuals with PD. In particular, the existing research results have proposed that the single word processing deficits might be due to a combination of deficits in linguistic and non-linguistic cognitive factors. According to research findings single word processing deficits may be due to grammatical deficits (Grossman et al., 1994; Peran et al., 2003), semantic deficits (Herrera et al., 2012) and executive dysfunctions (Colman et al., 2009). Table 4.3 provides a summary of the findings reported in this section.

Grossman, Stern, Gollomp, Vernon, & Hurtig (1994) evaluated the verb processing ability in a group of twenty individuals with PD with the task of learning new verbs in a naturalistic setting. Individuals with PD had to learn new verbs of very low frequency (e.g., wamble). The results revealed that 55% of individuals with PD had difficulty acquiring new verbs. Based on these findings, the authors concluded that this difficulty indicates the presence of a decreased grammatical processing ability.

Peran et al. (2003) investigated noun and verb processing abilities using generation tasks. The authors administered two intra-category tasks (noun/noun, verb/verb) and two inter-category tasks (noun/verb, verb/noun). In the intra-category tasks, the participants were required to generate a semantically related word (noun or verb) when listening to a noun or a verb whereas in the inter-category task the participants had to generate a noun or a verb when instructed to produce a semantically related item from the other category. According to the findings, PD participants had reduced accuracy in verb-related tasks. The authors claimed that the difficulty in verb retrieval ability is ascribed to the working memory and set-switching deficits. Also, they suggested that the results are linked to processing deficits of grammatical features due to frontal lobe dysfunction. In this case, the verb deficit is attributed to linguistic and non-linguistic processing deficits.

Bertella et al. (2002) assessed noun and verb naming ability in a group of twenty-two individuals with early-stage PD, and twenty matched healthy controls using a picture naming task. The picture naming task contained pictures of fifty-two objects and fifty pictures of actions. The results suggested that the PD group had difficulty in naming both objects and actions compared to healthy subjects. Moreover, the PD group's

naming accuracy for actions was significantly lower than that of objects. The authors suggested that action verbs were associated with frontal neural regions and the locus of lexical deficits is at the pre-lexical level.

Rodríguez-Ferreiro, Menéndez, Ribacoba, & Cuetos (2009) explored the noun and verb naming skills in twenty-eight individuals with PD. The stimuli consisted of fifty pictures of objects and fifty pictures of actions. Nouns and verbs were matched for the main psycholinguistic factors that affect the naming process (e.g., frequency, imageability, age of acquisition, number of phonemes, name agreement, visual complexity). The PD group showed greater naming difficulty with actions compared to objects. The authors claimed that verb retrieval ability activates a widespread neural circuitry that controls both motor planning and execution. Also, they suggested that the naming difficulty may be attributed to disruption of specific lexical representations.

Salmazo-Silva et al. (2017) explored the noun and verb retrieval ability and semantic processing skills using two-word association tasks in two different studies. They utilized action-verbs involving different body parts and nouns from several semantic categories (e.g., pets, wild animals, birds, fruits, household objects, small home objects, transportation and tools). The PD group had a worse performance on verb naming than noun naming. The authors performed a quantitative and qualitative analysis of naming error types. The results revealed that the main type of error in verb naming was of a semantic nature, specifically that of semantic circumlocutions. The PD group produced more generic verbs (e.g., "make wave" instead of "bye"). The authors attribute the verb naming deficit to degraded semantic representations within the lexicon.

A different group of studies have explored semantic processing deficits utilizing semantic association tasks. Fernandino et al. (2013a) compared action and abstract verb processing skills in PD. They recruited twenty participants with PD and twenty-two healthy controls. Three lexical tasks were administered. These included a lexical decision task, a task of priming and a semantic similarity judgment task. The individuals with PD had greater difficulty naming action verbs compared to abstract verbs on both tasks. The authors concluded that these results show that the motor system has an active role in semantic processing of action verbs.

The same group of authors Fernandino et al. (2013b) explored the action-related semantic processing skills of individuals with PD. They recruited twenty participants

with PD and twenty-one healthy controls. The participants were required to process four types of action-related sentences. The sentences were a) literal sentences (e.g., *the repairman bent the cable for her*); b) metaphoric sentences (e.g., *the congress pulled their support for the plan*); c) idiomatic sentences (e.g., *that question caught him off guard*), and d) abstract sentences (e.g., *the violent film changed all his ideas*). The results revealed that the PD group required more time to process the literal and idiomatic sentences compared to abstract sentences. The authors interpreted the results as an indication of the contribution of the motor system to action-related semantic processing as well as to metaphoric action language. The authors claimed that the motor system plays a critical role in processing of the semantic elements of action-related language. The results of the above studies provide evidence for the contribution of the motor system to the lexical processing especially during action related semantic processing of language.

4.8.4 The role of semantic variables in verb processing deficits.

There is now ample evidence that PD is associated with semantic processing deficits (Bak, 2013; Cousins & Grossman, 2017). One factor that may contribute to this discrepancy between the ability to name verbs and nouns in word production studies in PD may be the fact that the verbs are semantically more complex than nouns (Smith & Caplan, 2018). Several studies have explored the influence of specific semantic factors of action-verbs on word retrieval (Bocanegra et al., 2017; Cotelli et al., 2008; Herrera et al., 2012). Two motion-related semantic variables that have been studied to determine whether they influence verb retrieval abilities in PD are the manipulability features and the motor content of the verb.

Cotelli et al. (2007) assessed the noun-verb naming ability in a group of thirty-two participants with PD. Specifically, the study aimed to investigate the impact of manipulability on verb retrieval ability. According to the authors, the manipulable actions "*represent actions that involve fine hand movements*" (p. 632). The stimuli consisted of pictures of sixty nouns and sixty verbs. Both categories were matched for word frequency and word length. Each grammatical category was divided into manipulable and non-manipulable words based on the criterion of whether the objects can be manipulated or not and whether the actions involve fine hand movements or not. The PD group had difficulties naming for both actions, and objects, compared to healthy

controls. In particular, the PD group was significantly more impaired in action retrieval than in object retrieval. The semantic variable of manipulability did not influence the accuracy of naming ability. The authors also suggested that the action naming deficits may be attributed to disruption in prefrontal regions responsible for verb retrieval.

Another semantic variable that may influence the verb retrieval ability of individuals with PD is the motor content of verbs. In their study, Herrera et al. (2012) explored the role of the motor content of verbs on the lexical retrieval ability of forty-nine individuals with PD. They used two sets of pictures of fifty verbs that were categorized according to their motor content. One set consisted of twenty-five verbs with low level of motor content (e.g., "to sleep") and the other set included twenty-five verbs with high-level of motor content (e.g., to dig). The two sets of pictures were matched on the psycholinguistic variables of visual complexity, name agreement, lexical frequency, age of acquisition, imageability and number of syllables and phonemes. According to the findings, the PD group had greater difficulty retrieving verbs with high motor content compared to verbs with low motor content. The authors concluded, based on these results, that the verb retrieval deficits in PD are attributed to semantic deficits as the motor content is a semantic feature and not to the grammatical properties of verbs.

In another interesting study, Bocanegra et al. (2017) investigated the association between the cognitive abilities and the lexical retrieval ability of nouns and verbs. They recruited forty-nine individuals with PD and equal number of healthy controls. The PD group was further divided into two subgroups based on cognitive performance. One group of fifteen individuals was diagnosed with mild cognitive impairment (PD-MCI) and the other group of thirty-four with normal cognitive abilities (PD-nMCI). Forty pictures of nouns and forty pictures of verbs were used as stimuli. Specifically, two groups of twenty nouns with low and twenty nouns with high manipulability and twenty verbs with low and twenty verbs with high motor content. The authors explored the influence of the lexical-semantic variable of motor content of the verb on naming performance. According to the results, the PD-MCI group performed worse in retrieving all lexical categories (i.e., nouns with high/low manipulability/verbs with high/low motor content). However, the PD-nMCI group performed worse retrieving only the verbs with high motor content.

The authors concluded that the impairment in non-linguistic cognitive domains may affect the lexico-semantic processing skills in PD. Also, the results indicated that the lexico-semantic impairment may be present even in the absence of cognitive dysfunction. Based on the results of this study, the authors claimed that the naming difficulty may be ascribed to specific impairment in action-related semantic properties of verbs.

4.8.5 Neural basis for verb retrieval language disorders in PD

Several lines of evidence suggest that the disruption of fronto-striatal circuitry and of the basal ganglia (BG) contribute to language processing deficits in PD (Copland et al., 2021; Smith & Caplan, 2018). Clinical studies have suggested that the action verb processing deficits in PD are linked to damage to cortico-subcortical regions of the BG (Bartella et al., 2002; Cotelli et al., 2007; Ibanez et al., 2013). Also, the bilateral atrophy of the BG contributes to action language processing deficits (Melloni et al., 2015).

The action word deficits in PD are due to disruption of cortico-subcortical structures (Ibanez et al., 2013). It has been proposed that both cortical and subcortical brain areas contribute to action language processing (Cardona et al., 2013). Specifically, the motor and pre-motor areas are involved in processing of action words (Zhang et al., 2018). Also, the basal ganglia circuits are associated with the process of selection and retrieval of the target word. They enhance the activation of the selected lexical item and suppress the lexical alternatives (Bohsali & Crosson, 2016).

A limited number of studies have explored the neural basis for the retrieval deficits in PD. Evidence shows that action verb processing depends on the integrity of both cortical and subcortical areas (Garcia&Ibanez, 2014). The BG contributes to the processing of semantic and lexical information of words (Bocanegra et al., 2015).

To this end, Péran et al. (2009) explored the verb processing skills in fourteen non-demented individuals with PD combining verb processing tasks with functional magnetic resonance imaging (fMRI). The lexical tasks were picture-naming tasks of objects and actions. The pictures consisted of nouns that were man-made objects (e.g., screwdriver, key, scissors) and biologic objects that could be manipulated (e.g., duck, onion, mouse). In the first stage, the participants were required to name the object of the picture and for the second stage, they were required to generate a verb that was associated with the object of the picture. The PD group performed worse on the verb

production task. Furthermore, the results revealed that verb retrieval was linked with activation of frontal cerebral areas such as the prefrontal cortex, Broca's area and the anterior cingulate cortex. The authors suggested that verb retrieval deficits are attributed to the impaired semantic processing of action verbs.

Table 4.3: Key findings from the reported studies on verb-noun processing deficits in PD

Study	Participants	Lexical task	Material	Results
Bertella et al. (2002)	22 PD, 20 HCs	Picture Naming	52 pictures of objects, 50 pictures of action verbs	Verb retrieval more difficult than noun retrieval
Peran et al. (2003)	34 PD, 34 HCs	Word generation tasks: Noun to noun, verb to verb, noun to verb, verb to noun	40 concrete nouns, 40 action verbs	Difficulty with verb production
Cotelli et al. (2007)	32 PD, 15 HCs	Picture Naming	60 object pictures, 60 pictures of manipulable verbs	Verb and noun retrieval deficits, verbs more difficult than nouns
Rodriguez-Ferreiro et al. (2009)	28 PD, 28 AD, HCs	Picture Naming	50 object pictures, 50 action pictures	Verb and noun retrieval deficits, verbs more difficult than nouns
Herreira, Rodriguez-Ferreiro & Cuetos (2012)	20 PD, 15 HC	Picture Naming	25 high & 25 low motor content verbs	Verbs with high motor content more difficult than verbs with low motor content
Herreira et al. (2012)	49 PD, 19 HC	Picture Naming	25 verbs high & 25 verbs low motor content	Action-verbs with high motor content more difficult than the action-verbs with low motor content
Salmazo-Silva et al. (2017)	19+21 PD, 32+42 HC	Picture naming	64 nouns and 64 verbs (related to different body parts)	Actions verbs more difficult than nouns in PD group
Bocanegra et al. (2017)	15 PD-MCI, 15 PD-NC, 49 HC	Picture naming	40 object pictures with high/low manipulability and motion content	PD MCI showed impaired naming of objects of low/high manipulability actions & high/low motor content PD-NC showed impaired naming of actions with high motor content

4.8.6 Word production and executive functions

A number of clinical studies have explored the link between executive dysfunction and language deficits in PD (Colman et al., 2009; Crescentini, Mondolo, & Shallice, 2008; Grossman et al., 2002; Lee, Grossman, Morris, Stern, & Hurtig, 2003). To this end, some authors have argued that verb retrieval deficits are a dysexecutive disorder characterized by deficient selection processing ability during verb retrieval (Silveri, Traficante, Monaco, Iori, Sarchion, & Burani, 2018). Table 4.4 provides the key findings from reported studies on the impact of executive functions in verb retrieval in PD.

Colman et al. (2009) explored how executive functions (EFs) may influence the verb processing abilities in PD participants. They examined verb retrieval at the sentence level in twenty-eight individuals with PD and twenty-eight healthy participants. All participants were assessed on verb production in sentences as well as on cognitive functions. The neurocognitive tasks included tasks of working memory, set-switching ability, inhibitory control and verbal fluency. The PD group performed worse than healthy controls on the verb production task. The results showed that both groups had similar performance on tasks of verbal fluency and working memory. Verb retrieval ability was linked to working memory as well as to set-switching ability. The authors suggested that the association between verb retrieval ability and set switching deficits indicates that executive dysfunctions contribute to verb retrieval deficits.

In a different study, Bocanegra et al. (2015) investigated the impact of cognitive functions and executive functions on syntax processing skills and on action-related language skills. They recruited three different groups of participants. The first group consisted of twenty-three participants with intact cognitive functions (PD-nMCI), the second group consisted of seventeen participants with cognitive impairment (PD-MCI) and the third group was that of forty healthy controls. The lexical tasks included syntactic processing, action-verb naming, and action-related semantic processing. Participants with PD showed deficits in the tasks of executive functions, syntactic processing ability, verb retrieval ability, verb and noun semantic processing compared to the control group. Executive dysfunction was associated with reduced accuracy in syntactic processing and objects naming. However, verb production was not related to

executive dysfunction. These findings suggest that verb processes apart from other language processes and executive functions might be associated with BG functioning.

Another important finding of this study is that the action-verb retrieval deficits can occur in the early stages of the course of the disease and may be independent to executive dysfunction. Executive functions served as predictors of performance on syntactic processing tasks regardless of the presence/not of cognitive impairment. This was an indication that processing ability of action verbs is not associated with executive functions. In fact, executive functions were associated with syntactic and object processing deficits in the presence/not of cognitive impairment. Executive functions had no impact on action naming or semantic association difficulties in both PD groups. On the other hand, syntactic deficits and object-related semantic deficits were attributed to executive dysfunction.

The results revealed that the action-related language deficits specifically in the tasks of naming and semantic processing may be independent of the cognitive dysfunction as well as executive functions. Overall, the findings suggest that executive dysfunction can affect specific language processes (e.g., syntax, noun retrieval) but leave other language processes unaffected (e.g., verb retrieval). Similarly, Silveri et al. (2012) did not find an association between verb naming ability and executive functions.

Table 4.4: Key findings from reported studies on the impact of executive functions in verb retrieval

Study	Participants	Lexical task	Results
Colman et al. (2009)	28 PD, 28 NC	Verb production in sentence context	Verb naming was associated with executive dysfunctions (i.e., set-switching deficits)
Bocanegra et al. (2015)	23 PD-nMCI 17 PD-MCI 40 HC	Syntactic processing, action-verb naming, action related semantic processing	Verb production/semantic deficits independent of the presence of cognitive dysfunction and executive function deficits

4.8.7 Semantic complexity and verb retrieval ability

As previously mentioned, a factor that may be critical for the retrieval of verbs is the semantic complexity of verbs. Breedin, Saffran, & Schwartz (1998) proposed the Semantic Complexity Hypothesis that posits that the semantic complexity of verbs plays a crucial role in retrieval processes. This theory holds that the retrieval of semantically complex verbs is easier compared to semantically simple verbs. This may be attributed to the fact that the semantically complex (*heavy*) verbs are associated with the activation of one meaning whereas the semantically simple verbs (*light*) are associated with the activation of more than one meaning related to the target word. Gordon & Dell, (2003) described the differences between *heavy* and *light* verbs as follows:

"They belong to the same category and occupy similar semantic spaces but differ quantitatively along several dimensions: light verbs by definition are specified by fewer semantic features than are heavy verbs; they are also less constrained by semantic context and consequently occur more frequently than heavy verbs " (p.7)

They also provided a specific example to illustrate this difference:

The light verb "go" consists of semantic features (i.e., to move from one place to another) which form part of the definition of heavy verbs such as "fly"(i.e., to move from one place to another through the air) and "run" (i.e., to move from one place to another rapidly by springing steps)" (p.6)

One semantic-conceptual factor that is related to semantic complexity and could influence verb retrieval abilities is the instrumentality factor. Instrumentality is a variable that concerns both nouns and verbs and it can be dichotomized into two main categories *instrumental* and *non-instrumental* nouns and verbs. This distinction is made based on whether the action of the verb requires an instrument to be performed.

Instrumental verbs require the use of an instrument. For example, the verb *to dig* assumes a spade (instrument) to carry out the action. On the other hand, non-instrumental verbs represent actions that do not require an instrument in order to be performed such as *to kneel*, *to climb* etc (Jonkers & Bastiaanse, 2007). Also, the semantic representation of an instrumental verb includes the information about the required instrument and as a consequence they are considered to be *semantically complex* or *heavy verbs* as opposed to non-instrumental verbs that are considered to be *semantically light verbs* (Koenig, Maurer, Bienvenue, & Conklin, 2008). In addition to

the semantic features of instrumental verbs, it is important to mention that the retrieval of an instrumental verb activates the conceptual representation of both the verb and the noun (Bastiaanse, 1991; Jonkers & Bastiaanse, 2007).

An additional concept related to the instrumental verb is the factor of *name relation*. Name relation is defined as the phonological similarity between a noun and a verb ('hammer' (noun) - 'to hammer' (verb)). Name relation is a phonological factor that may affect the accuracy of the verb retrieval abilities of speakers (Jonkers & Bastiaanse, 2007; Kambanaros, 2003).

A large body of research has been published on the effect of instrumentality and name relation on verb naming ability in different clinical populations with focal and non-focal brain pathologies including stroke induced aphasia (Bastiaanse, 1991; Jonkers & Bastiaanse, 2007; Kambanaros, 2003; Kambanaros, 2009; Kambanaros & Van Steenbrugge, 2006; Kambanaros, Messinis & Anyfantis, 2012; Kemmerer & Tranel, 2000; Malyutina, Iskra, & Sevan, 2014) and other neuropathologies (Kambanaros & Grohmann, 2015). Tables 4.5 and 4.6 provide a summary of the findings from the reported studies.

It is worth noting that the above studies included participants that were monolingual speakers of different languages such as English (Kemmerer & Tranel, 2000), Dutch (Jonkers & Bastiaanse, 2007), Russian (Malyutina et al., 2014) and Greek (Kambanaros et al., 2016).

Table 4.5: Studies reporting on the effects of instrumentality and name relation on verb retrieval

Authors	Language	Lexical task	Medical diagnosis	Effect of instrumentality	Effect of name relation
Kambanaros et al.(2010)	Greek	Verb Naming	Schizophrenia	<i>negative</i>	<i>negative</i>
Sloot & Jonkers (2011)	Dutch	Verb Naming	Alzheimer's Disease	<i>positive</i>	<i>negative</i>
Kambanaros (2013)	Greek	Verb naming	SLI	<i>negative</i>	<i>positive</i>
Kambanaros et al. (2016)	Greek	Verb Naming	Multiple Sclerosis	<i>negative</i>	<i>positive</i>

Table 4.6: research on the effects of instrumentality and verb-noun name relation on verb retrieval in stroke induced aphasia

Authors	Language	Lexical task	Type of aphasia	Effect of instrumentality	Effect of name relation
Bastiaanse (1991)	Dutch	Verb Naming	Fluent /Non-fluent	None in both types of aphasia	Negative in both types of aphasias
Kambanaros & Van Steenbrugge (2006)	Bilingual speakers Greek-English	Verb Naming	Fluent	Positive in both languages	Negative in both languages
Jonkers & Bastiaanse (2007)	Dutch	Verb naming	Non-fluent/fluent	Positive in anomic aphasia/none in Broca's aphasia	No effect in both groups
Kambanaros (2009)	Bilingual speakers Greek-English	Verb in a sentence	Fluent (n = 12)	None in both languages	No effect in Greek, negative in English
Kambanaros, Messinis, Anyfantis (2014)	Greek & English	Written naming of verbs	Fluent (n=1)	None in both languages	No effect in either language

4.8.8 Words related to tools

A further area of interest related to the instrumentality factor is the research that concerns the words that are related to tools. These tool-related words are associated with the conceptual representations corresponding to their usage and the semantic features of the tool (Lewis, 2006). On the other hand, the processing of verbs that require the usage of a tool activates an extensive neural network that includes frontal–

parietal–temporal cerebral areas. This includes cerebral regions responsible for motor control as well as tool knowledge (Yang, Shu, Bi, Liu, & Wang, 2011). Specifically, verbs related to tools activate left superior parietal lobule, left middle frontal gyrus and left posterior middle temporal gyrus (Yang et al., 2011).

4.9 Conclusion

From the studies reviewed in this chapter, there is a strong case, that different elements of lexical processing (e.g., lexical retrieval, sentence processing, metaphor processing) are affected in PD, and this breakdown in language processing across different linguistic tasks is often associated with other non-linguistic cognitive deficits such as executive dysfunctions. The findings suggest that individuals with PD have difficulty retrieving nouns and verbs compared to healthy controls. Moreover, action-verb production is more difficult than nouns. The factors that may affect verb retrieval ability in PD are as follows:

- (i) The semantic factor of the motor content of verbs may play a crucial role in retrieval ability. Specifically, individuals with PD are expected to have difficulty in retrieving verbs with high motion content.
- (ii) The greater difficulty naming action verbs compared to nouns is associated with widespread neural network including areas responsible for motor planning and execution as well as areas corresponding to semantic and lexical representation.
- (iii) The fact that action- verb retrieval deficits are due to semantic impairments may exclude the hypothesis that the grammatical nature of verbs contributes to these deficits.
- (iv) A common speculation based on the findings of the current clinical studies is that action-verb processing deficits in PD are commonly attributed to disruption of pre-frontal areas and frontal-subcortical circuits.

4.10 Summary

From the studies reviewed in this chapter, it can be concluded that different elements of lexical processing (e.g., lexical retrieval, sentence processing, metaphor processing) are affected in PD, and these language disorders are often associated with other non-linguistic cognitive deficits such as executive dysfunctions. Considering the research evidence mentioned earlier in this chapter it can be concluded that PD is characterized by language disorders as part of its complex symptomatology.

Several clinical studies have suggested that language skills are preserved in the early stages of PD. It should be noted that most of these studies aimed to explore the neuropsychological profile of PD participants and therefore a limited number of the linguistic tasks were administered. It is important to mention that the studies that produced this body of evidence have come to this conclusion because they assessed the language skills via common visual confrontation naming tests (e.g., Boston Naming Test) that predominantly include nouns as stimuli. However, other studies have produced opposing evidence supporting that the language skills are deficient in the early stages. The most prominent reason is that these studies utilized more demanding linguistic tasks such as action-verb naming. It is now accepted that action words are sensitive markers of linguistic deficits in PD and are frequently affected even in the earliest stages of the disease.

A matter of debate in the language study literature on PD is whether the language disorders are exclusively attributed to damage to the language faculty or access to the linguistic system or a byproduct of the cognitive impairment. However, a clear-cut answer on this matter is yet available.

In conclusion, the current clinical findings suggest that PD is characterized by impaired verb and noun retrieval, sentence processing deficits, and metaphor and idiom processing skills.

Chapter 5: Research aims

The previous chapters presented the clinical characteristics of cognitive and linguistic deficits in PD. This chapter aims to present the grammatical features of Greek language as well as the research questions.

5.1 Studies in Greek Language

A very limited number of studies have investigated the cognitive and linguistic abilities of Greek-speaking individuals with PD. Natsopoulos et al. (1993, 1991) explored the processing ability of syntactically complex sentences (relative clauses, multi-clausal sentences) of Greek-speaking individuals with PD. The results indicated that PD participants had difficulty processing such complex sentences. The authors interpreted this difficulty to be attributed to impaired ability to utilize the required mental strategies and syntactical operations to process the sentences.

Terzi et al. (2005) explored the processing skills of passive sentences in a group of non-demented individuals with PD. The results revealed that PD participants had difficulty producing the passive form of verbs. Interestingly enough, the authors suggested that the language impairment is not purely linguistic in nature, but it is due to reduced computational demands, however this was not directly tested.

The literature so far, brings to light a limited number of studies that have explored language disorders in Greek speaking individuals with PD. Furthermore, these studies have investigated language processing abilities only at the sentence level with a focus on complex syntactic operations. No studies, so far, have explored single word processing skills (e.g., confrontation naming of verbs and nouns) or complex language processing (e.g., metaphor or idiomatic language processing) in Greek for patients with PD.

5.2 Grammatical features of Greek Language

Since this research project involves Greek-speaking participants, it is important to present a mini overview of the linguistic features of Standard Modern Greek (SMG). SMG belongs to the family of Indo-European languages and is a highly inflected stem-based language with rich morphology (Holton, Mackridge & Philippaki-Warbuton, 1997). The main difference between nouns and verbs are that nouns are marked for gender, number, and case, whereas verbs are marked for person, number, tense, aspect,

and voice. Both verbs and nouns are considered to have similar morphological, inflectional complexity. Another important feature of MG is that it is a pro-drop language with a free word order.

Regarding the morphological structure, both nouns and verbs consist of a stem that does not represent a real word. For example, the noun "σκούπα" (the Greek word for 'broom') consists of the stem "σκούπ" and the attached suffix -α. The suffix -α conveys several grammatical features of (i) gender, it is *feminine*; (ii) number, it is a *singular* and (iii) *case*, it is nominative (see figure 5.1).

On the other hand, the verb "πίνω" (the Greek word for *I drink*) consists of the stem πίν- and suffix -ο and represents the grammatical features of verbs of number, it is first person, singular verb. The suffix in Greek conveys the grammatical and semantic information of the word (see figure 5.2).

The Greek stem "πίν" of the verb "πίνω" (translation: *I drink*) conveys some semantic information but no meaning, since the stem is not inflected. The inflection adds meaning to the word stem of Greek verbs and nouns by creating a real word.

During noun and verb confrontation naming tasks, both grammatical and lexical properties of the word must be retrieved.

The fact that SMG is a highly inflected language may influence noun and verb retrieval abilities in Greek-speaking individuals potentially in two ways.

Firstly, both verbs and nouns are considered morphologically complex and therefore they demand more computational resources compared to other languages. This might have an impact on the profiling of single word retrieval deficits of different clinical conditions in Greek-speaking populations with respect to severity of the naming disorders (Kambanaros & Grohmann, 2015).

Secondly, both nouns and verbs are characterized by the same degree of inflection that would suggest that both grammatical word classes are characterized by the same level of retrieval difficulty.

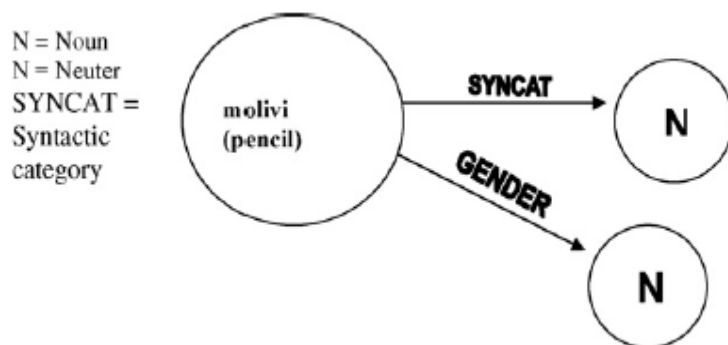


Figure 5.1: Grammatical features of the Noun lemma

(from Kambanaros, 2008, with permission from the author)

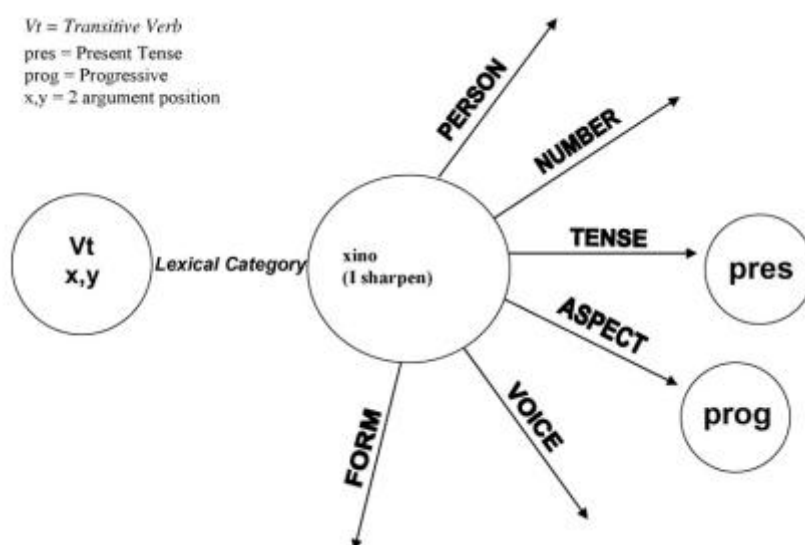


Figure 5.2: Grammatical features of Verb lemma

(from Kambanaros,2008, with permission from the author)

5.3 Research Questions

The present study aims to explore the linguistic deficits in PD in non-demented Greek-speaking individuals with PD.

Rationale

Aims

The present research was conducted in order to expand our understanding of the language processing abilities of Greek speaking individuals with PD.

The main objectives was to explore the linguistic and cognitive profile of non-demented individuals with PD. The language areas that were explored included low level and high-level language tasks as follows:

- (1) Confrontational naming of nouns and verbs
- (2) Sentence repetition
- (3) Metaphor and idiomatic processing

The cognitive functions that were assessed included:

- (1) Verbal working memory
- (2) Executive functions

The specific aims of this study were:

- (1) To compare the cognitive abilities between a group of individuals with PD and healthy controls. It is expected that the two groups will be different in tasks of executive functions. It is proposed that executive dysfunction is a common cognitive deficit in non-demented participants with PD.
- (2) To investigate whether individuals with PD show verb–noun dissociations on naming tasks. Based on findings of the previous studies the prediction was that individuals with PD will perform worse on naming of both nouns and verbs compared to healthy participants and that the individuals with PD will have greater difficulty in naming nouns and verbs than healthy controls.
- (3) To explore whether there is a difference on naming accuracy between the semantically heavier (instrumental) verbs and the semantically lighter (non-instrumental) verbs for patients with PD. Based on results of previous studies the prediction would be that the semantically complex verbs would be more difficult compared to non-instrumental verbs.
- (4) To explore whether naming performance for verbs and nouns of the PD group is influenced by any of the psycholinguistic variables of the target stimuli (e.g., word frequency, age of acquisition, imageability, and picture complexity).
- (5) To explore whether naming performance for verbs and nouns in the PD group would be influenced by i) characteristics of the disease (i.e., duration, severity of motor

symptoms), and ii) by performance on cognitive abilities (e.g., attention, memory, executive functions).

(6) To explore whether the participants with PD would have difficulty processing different types of sentence constructions (syntactically simple sentences, syntactically complex sentences) on a sentence repetition task with targeted structures. The hypothesis is that the PD group would not have any difficulty repeating sentences.

(7) To evaluate the ability of the participants with PD to process metaphors. The current body of the research reveals that individuals with PD have difficulty processing metaphoric expressions. The hypothesis is that the PD participants will have difficulty processing metaphors because of the cognitive demands of this task.

(8) To investigate whether the cognitive deficits associated with PD predict the linguistic deficits in the PD group. The prediction is that the cognitive impairment in specific non-linguistic cognitive domains such as executive functions will predict the abilities with linguistic skills.

Chapter 6: Methodology

A cross-sectional research design was chosen to best serve the aims of this study. Wang & Cheng (2020) defined the cross-sectional design *"as a type of observational study design that involves looking at data from a population at one specific point in time. In a cross-sectional study, investigators measure outcomes and exposures of the study subjects at the same time"* (p.556).

This study was conducted in two stages. The first stage included the recruitment of participants as well as their neurological examination. The participants that met the inclusion criteria, were administered a battery of neurocognitive measures to assess cognitive abilities. In the second stage the participants were administered all the linguistic measures.

6.1 Participants

The study consisted of two participants groups, twenty-four individuals with idiopathic PD and fifteen healthy controls (HCs). The two groups were matched for age, years of education (See Table 6.1 for means and statistical significance). All the individuals with PD were outpatients of the Neurology Clinic of the General University Hospital of Ioannina, Greece. Parkinson Disease was diagnosed according to United Kingdom Parkinson's Disease Society Brain Bank diagnostic criteria (Hughes et al., 1992). A neurologist with expertise in motor disorders made the medical diagnosis of PD for all individuals and acquired case history information about the clinical characteristics such as duration of the disease. He also administered the clinical scales of the Unified Parkinson Disease Rating Scale and the Hoehn& Yahr to assess the severity of PD motor symptoms (Table 6.2). In the first session, all information on disease history and clinical data were acquired. All PD participants were taking anti-parkinsonian medication and were in the "on" state during the clinical examination. In the second session, the participants were administered all the linguistic tasks. All participants were monolingual native Greek speakers. The neurocognitive tasks followed in a third session. The administration of all the neurocognitive and language tasks was undertaken in a quiet room.

The participants with PD to be included in this study had to meet the following inclusion criteria:

- (a) Educational level of at least 6 years (primary school graduates in Greece).
- (b) Greek as native language.
- (c) Performance on the Greek adapted version of the Mini –Mental State Examination score (MMSE) ≥ 26 .
- (d) Provision of written informed consent to take part in the study.

Exclusion Criteria

Exclusion criteria were as follows:

- (a) Presence of major psychiatric disorders (e.g., psychotic symptoms or disorders, illegal drugs, or alcohol abuse).
- (b) Presence of another neurological disorder (e.g., dementia, stroke, epilepsy, traumatic brain injury).

Exclusion criteria for the healthy participants were:

- (a) History of psychiatric, neurological, or cardiovascular disorders or of substance abuse or dependence (including alcohol and benzodiazepine abuse).
- (b) Any other medical condition (including hearing impairment) that might affect test performance.
- (c) Non-native speakers of the Greek language.
- (d) Performance of less than 27 on the Greek validated version of the Mini-Mental State Examination.

Table 6.1: Demographic data for participants by group.

	PD (n=24)	HCs (n=15)	Sign.
Age (years)	65,83 (8,14)	63,53 (6,14)	U=205.50, $p=.469$
Education (years)	10,21 (3,65)	11,73 (3,49)	U=138.000, $p=.215$
MMSE(/30)	28,42 (1,18)	28,87 (0,64)	U=144.500, $p=.282$
BDI	2.54(1.14)	2.46(0,74)	U=178.500, $p=.963$

All variables are reported as means (*standard deviation*); PD: Parkinson Disease Patients; HC: healthy controls; MMSE: Mini Mental State Examination; BDI: Beck Depression Index

Depressive symptoms were also assessed with the Beck Depression Index (Giannakou, Kosmides, Kiosseoglou, & Garyfallos, 2013). Both groups had scores below 17 indicating depression.

Table 6.2: Disease Characteristics of individuals with Parkinson’s disease

PD only variables	M (SD)	Range (min-max)
HYS (/5)	2,06(0,57)	(1-3)
UPDRS-III (/72)	26,95(5,93)	(18-38)
Duration of PD symptoms (years)	4,04(3,01)	(1-11)

Keys: HYS= Hoehn &Yahr Staging; UPDRS: Unified Parkinson Disease Rating Scale

Ethical Considerations

The study was approved by the Medical Ethics Committee of the General Hospital of the University of Ioannina. All participants signed a written informed consent before the study.

6.2 Materials

6.2.1 Neuropsychological tasks

To assess the cognitive skills of both groups, four neuropsychological tests were administered.

6.2.1.1 The Greek version of the Mini Mental State Examination

The Greek version of the Mini Mental State Examination (MMSE; Fountoulakis, Tsolaki, Chantzi, & Kazis, 2000) was administered to assess global cognitive functioning. The MMSE is a brief screening measure for global cognitive ability, and it was administered to rule out severe cognitive deficits and dementia. The test consists of 30 items and assesses orientation, memory, concentration, auditory comprehension, and naming and repetition ability to follow verbal and written instructions as well as assessment of spontaneous sentence writing and copying a complex figure of two pentagons. In Greek MMSE a performance lower than 24 is indicative of severe cognitive impairment or dementia.

6.2.1.2 Digit Span Test

Digit Span Test (DST; Wechsler, 1987) evaluates the short-term verbal memory through measures of attention span via digit span forward (DSF) and working memory via digit span backward (DSB) (Richardson, 2007). In both measures the participant is required to repeat digit sequences in forward and backward order. Digit sequences begin with a length of three digits and increases up to eight digits. Two trials are presented at each increasing list length. Testing ceases when the subject fails to accurately repeat either trial at one sequence length or when the maximal list length is reached (9 digits forward, 8 backward).

6.2.1.3 The Greek version of Trail Making Test

The Greek version of Trail Making Test (TMT; Zalonis et al., 2007) was administered to measure executive functions. It consists of two parts, TMT-A and TMT-B.

Regarding the specific cognitive abilities that each part assesses the TMT-A measures attention, visual scanning, speed of eye-hand coordination as well as information processing. TMTB is a measure of the individual's ability to alternate between two cognitive sets of stimuli set switching ability.

Both parts are composed of 25 circles distributed over a sheet of paper. In TMT-A, the circles are numbered from 1 to 25. The patient is required to connect the numbers by drawing a line, in ascending order.

In TMTB, the circles include both numbers (from 1 to 13) and letters (from A to M), and the patient must draw lines to connect the circles in an ascending order alternating between numbers and letters (i.e., 1–A–2–B–3–Γ, etc.).

The participant is instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. The score represents the number of seconds required for the task completion.

6.2.1.4 Verbal Fluency Task

The Verbal Fluency Task (VFT; Kosmidis, Vlahou, Panagiotaki, & Kiosseoglou, 2004) has a semantic (SF) and a phonemic component (PF). The verbal fluency test was administered according to the instructions described in Kosmidis et al., (2004).

On the semantic test, the participant is required to recall as many different words as possible that belong to a specific semantic category. The three semantic categories are: animals, fruits, and objects.

On the phonemic test, the participant is required to recall as many different words as possible beginning with a specific letter. The three Greek letters that are used in this task are X (*Chi*), S (*Sigma*), and A (*Alpha*).

Tests of verbal fluency (VF) require time-restricted generation of multiple response alternatives under constrained search conditions. VF also involves associative exploration and retrieval of words based on phonemic or semantic criteria (phonemic or letter fluency, and semantic or category fluency, respectively). Both measures require efficient organization of verbal retrieval and recall, as well as self-monitoring aspects of cognition (the participant must keep track of responses already given), effortful self-initiation, and inhibition of responses where appropriate (Henry & Crawford, 2004).

The semantic test (animals first, fruit second, and objects third) was administered prior to the phonemic test, in the same order for all participants.

6.2.2 Language Tasks

To assess the language skills of both groups three language tests were administered.

6.2.2.1 The Greek Object and Action Test

The Greek Object and Action Test (GOAT) (Kambanaros, 2003) is a picture based task developed in order to assess the noun and verb naming abilities of Greek speaking patients with different pathologies. It has been administered in a number of clinical studies (Kambanaros et al., 2010; Kambanaros et al., 2016; Kambanaros, 2008) to explore the single word processing skills in different populations with potential linguistic deficits (e.g., Multiple Sclerosis, Schizophrenia, Stroke induced aphasia, Specific Language Impairment).

Test description

Single words

All verbs and nouns that were used for the single word processing subtests of the GOAT were professionally photographed in a studio. One male and female actor were used for all action pictures. Actions were equally divided into actions performed by a male and actions performed by a female. There are 84 photographs in total (42 objects; 42 actions). Each photograph is in colour, measuring 10cms x 14 cms in size.

Comprehension test

Verb comprehension was evaluated with a spoken-word-to-picture matching task consisting of forty-two words divided into twelve non-instrumental verbs and thirty-five instrumental verbs: fourteen without a name relation to the related instrumental noun and sixteen with a name relation. The distractors were semantically related verbs. Both the target and the distractor verbs were matched with the target verbs for frequency, instrumentality, and name relation. Whenever the target was for example, an instrumental verb the distractors were also instrumental verbs. Two distractor verbs were matched with the target verb. For example, the verbs ‘sawing’ (name related) and ‘painting’ (instrumental) were the distractor verbs for the target verb ‘hammering’.

Noun comprehension was evaluated with a spoken-word-to-picture matching task consisting of forty-two items divided into twenty non-instrumental nouns and thirty-five instrumental nouns: twenty without a name relation to the related instrumental verb and fifteen with a name relation. Two distractor nouns were matched with the target noun. The distractors were semantically related nouns. Both the target and the two distractor nouns were matched for frequency and instrumentality. Whenever the target was an instrumental noun, the distractors were also instrumental nouns. For example, the nouns ‘saw’ (name related) and ‘paint brush’(instrumental) were the distractor nouns for the target noun ‘hammer’.

Production tests

Action naming was a naming task comprising forty-two words divided into twelve non-instrumental verbs and thirty instrumental verbs. The instrumental verbs were further divided into two groups. One group comprising fourteen verbs without a name relation to the related instrumental noun and the other group comprising sixteen verbs with a

name relation. The pictures were designed to elicit a single action verb. All target verbs in action naming were also targets in verb comprehension.

Procedure

Pictures were presented to each participant individually. The ordering of the items in each test was random. All participants were tested individually in a quiet room of their choice. All participants were given two examples in each subtest prior to testing. After the examples no additional feedback was given. No time restrictions were placed.

Comprehension

For *object and verb comprehension* the same procedure was followed. Each participant was shown four photographs (placed horizontally on the table). He/she was asked to point to the picture of the object matching the word he had just heard. Each triad of photographs was presented randomly in each subtest. If the subject failed to point to the correct picture they were corrected. For participants who pointed to more than one photograph they were told only one picture was correct. The instructions were repeated for subjects who did not point to any pictures. No time limits were placed, and self-correction was allowed. Only once was the target word repeated upon participant request. If further repetitions of the same word were required, the answer was scored as incorrect.

Production

For *object/noun naming* each participant were shown single photographs in random order and asked to name the object in the photograph. For *action naming* the participants were instructed to describe in one word what the person in the photograph was doing (now). The stimulus photographs were presented in random order. The stimulus question(s) was repeated once for subjects who did not respond. If no response was given, the item was scored as incorrect. No time limits were placed, and self-correction was allowed

Tested variables

Several psycholinguistic variables have been shown to influence verb/noun retrieval in neurotypical and neuropathological populations. These include imageability, familiarity, frequency, transitivity, instrumentality, and name relation. Each of these variables were controlled for in the GOAT as follows:

Transitivity

All verbs included in the GOAT were non-relational and active. They took a single argument i.e., were mono-transitive and denoted a simple physical action. The instrumental verbs were specifically controlled for the thematic structure of the verb as *Verb + theme*, the theme representing the instrument. Non-instrumental verbs had the thematic structures *Verb + agent/patient*.

Instrumental verbs and name relation with a noun

Instrumental verbs represent actions that require an instrument (not a body part) to be carried out. The verbs ‘to cut’ (κόβω), ‘to brush’ (βουρτσίζω) and ‘to hammer’ (καρφώνω) belong to category of instrumental verbs, whereas the verbs ‘to sleep’ (κοιμάμαι), ‘to climb’ (σκαρφαλώνω) and ‘to fold’ (διπλώνω) are regarded non-instrumental verbs. In addition, the category of instrumental verbs can further be divided into verbs that are related in name with a noun/instrument/ ‘(hammer (σφυρί) - to hammer (καρφώνω) , brush (βούτσα) - to brush (βουρτσίζω) and those that are not broom (σκούπα) - to sweep (σκουπίζω), scissors ψαλίδι- to cutκόβω’.

Instrumental nouns

Forty-two nouns were used for object naming were the instruments/manipulated objects that belonged to the instrumental verbs. Sixteen of these had a name relation with the verb and the other fourteen were without a name relation. All manipulated nouns included items from the semantic category of tools/manipulated implements. Items from other semantic categories such as clothing that can be manipulated e.g. “tie”- “tying” were excluded because they are not considered to be true instruments. All other nouns representing common objects were from several semantic categories such as furniture, household items, clothing, vehicles, etc. Furthermore, all nouns included in the GOAT were inanimate nouns. The GOAT stimuli are presented in Appendix A and D.

6.2.2.2 The Greek Sentence Repetition Test (GrSRepT)

The Greek Sentence Repetition Test (GrSRepT) (Chondrogianni, Andreou , Nerantzini, et al., 2013) was administered in order to assess the morphosyntactic abilities in

individuals with PD. The GrSRepT includes 32 sentences with complex syntactic structures. Specifically, the sentences encompass operations from 8 different syntactic structures: *subject-verb-object*, *negation*, *wh-questions*, *coordination*, *adverbials*, *clitic doubling/left dislocation*, *relative and complement clauses*. Each syntactic structure has 4 sentences. The task items comprised of sentences with length that varies from 9 to 12 words and from 17 to 23 syllables. The evaluation of the performance of repetition ability included quantitative and qualitative error analysis. The performance of each participant was evaluated at both sentence and word level. In particular, at the sentence level each item was scored on overall correctness. At the word level each repetition was evaluated on *word omissions*, *substitutions*, *additions* and *word order errors* for both content and function words. The examiner presented each sentence with natural pronunciation and intonation. The participant was instructed to repeat the sentence verbatim. Each sentence was presented once. The stimuli sentences are presented in Appendix B.

6.2.2.3 Test of Idioms and Metaphors (TIM)

The TIM (Kambanaros, 2015) includes two subtests, a comprehension and production subtest with 30 stimuli sentences in each. For the comprehension subtest that includes metaphoric and idiomatic sentences the participants had to read the sentence and choose the one that matched the target sentence in meaning with from three other sentences. For production, the shortened version of the production subtest was used, that has 15 items. The participants were required to provide the meaning of the target sentence in their own words. The TIM stimuli are reported in Appendix C

Table 6.3: Neurocognitive and Linguistic Measures

Domain	Measures
<i>General Cognitive Functioning</i>	Mini Mental State Examination (Fountoulakis et al., 2000)
<i>Executive Functions</i>	<ul style="list-style-type: none"> ➤ Trail Making Test: Part-A, Part-B (Zaloni et al., 2007)) ➤ Digit Test Span: Digit Forward Span: attention span, Digit Backward Span: verbal working memory) ➤ Verbal fluency Test (semantic and phonemic) (Kosmidis et al., 2004)

<i>Language Functions</i>	
<i>Naming</i>	The Greek Object & Action Test (GOAT: Kambanaros, 2003)
<i>Morphosyntax</i>	The LITMUS Sentence Repetition Test (Chondrogianni et al, 2013)
<i>Pragmatic language</i>	The TIM (Kambanaros, 2015)

6.3 Procedures

Each participant was tested individually in a quiet room. A battery of neurocognitive tests was administered to assess cognitive functions. Measures that evaluated global cognitive functioning, attention span, verbal working memory, visual scanning/psychomotor speed, and executive functions. All measures have been adapted and standardized for the Greek population and were executed according to the instruction manuals or the published normative studies (see reference section).

Chapter 7: Results

This chapter is devoted to the statistical analysis incorporating the results from the research measures. The results are presented according to group performance on neuropsychological as well as on linguistic tasks.

All statistical analyses were performed using SPSS version 26. The normality assumption of the data was initially investigated using the Shapiro-Wilk test. The Bartlett test was used for exploring the equality of variances. To investigate the equality of means of the two groups two samples t-tests were used for normally distributed variables, and the Mann-Whitney U test for variables not normally distributed. To explore the correlation of different variables Spearman's test correlation was used. An alpha level ≤ 0.05 for statistical significance was set in all analyses.

7.1 Demographic variables

The analyses of demographic confounding variables did not reveal significant differences between the two groups regarding age ($U=205.50$, $p=.469$), years of education ($U=138.000$, $p=.215$) and gender ($\chi^2=.508$). Moreover, no significant difference was observed between the two groups on the MMSE score ($U=144.500$, $p=.282$). Group differences regarding gender were examined using χ^2 analysis. No significant difference was noted.

7.2 Performance on neurocognitive tasks

Analyses of the neurocognitive test data revealed statistically significant differences between the two groups on the TMT-A ($U=299.500$, $p=.001$), TMT-B ($U=276.000$, $p=.006$) and phonemic fluency ($t=-2.261$, $p=.03$). No significant differences between groups were found on the DSF, DSB and semantic fluency (see Table 7.1). The overall results across neurocognitive measures between the two groups are graphically depicted in a bar graph below (see graph 7.1).

Table 7.1: Performance on neurocognitive measures for PD and healthy control groups

	PD(n=24)	HCS(n=15)	Statistical significance
DSF	6,67 (1,61)	7,13 (1,81)	$p=.406$
DSB	5,71 (1,52)	6,07 (1,1)	$p=.433$
TMT-A ^a	66,88 (32,25)	39,53 (8,31)	$U=299.500,p=.001$
TMT-B ^a	159,42 (94,67)	87,13 (42,02)	$U=276.000,p=.006$
Semantic Fluency	49,83 (14,19)	54,87 (4,55)	$p=.118$
Phonemic Fluency	26,62 (10,68)	34,73 (11,24)	$t= -2.261,p=.03$

All variables are reported as means (standard deviation). PD: Parkinson Disease patients, HC: healthy controls, DSF: Digit Span Forwards, DSB: Digit Span Backwards, TMT-A:Trail Making Test -A,TMT-B:Trail Making Test-B, n.s: non-significant, ^ahigher scores indicate worse performance.

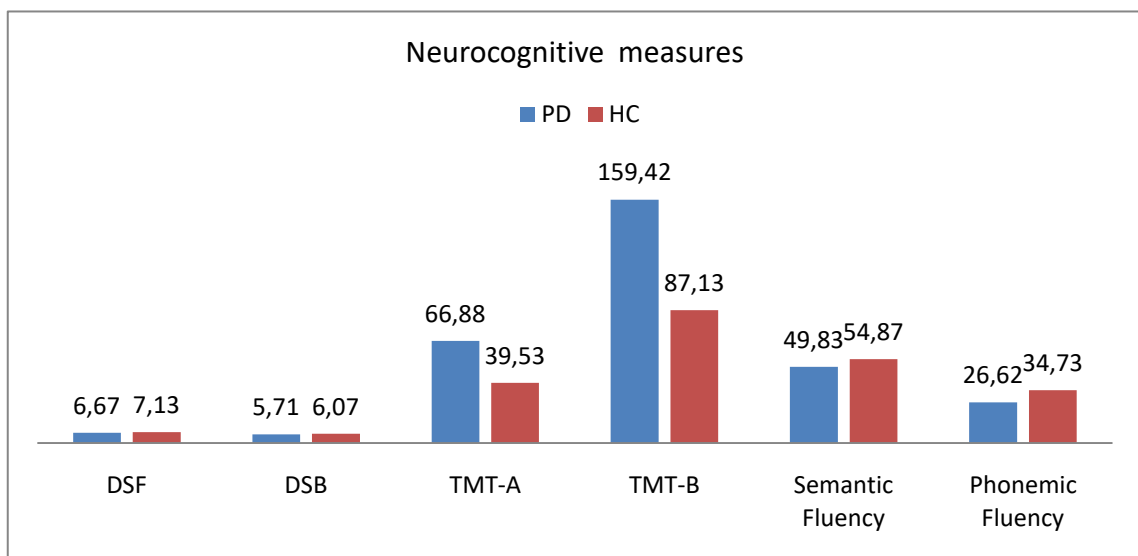


Figure 7.1: Overall performance on neurocognitive measures between the PD group and the HC group.

7.3 Performance on the GOAT (noun-verb naming)

Analyses of performance on the GOAT showed statistically significant differences between the two groups for noun retrieval ($t= -2.138, p=.039$) and verb retrieval ($t=-3.064, p=.004$). Statistically significant differences were noted between the two groups on naming of non-name related instrumental nouns ($U=95.000, p=0.010$), non-instrumental nouns ($U=111.000, p=0.037$) and on name-related instrumental verbs

($U=83.000$, $p=0.005$). The total verb production was significantly worse than total noun production ($t=.223$, $p=.000$) in individuals with PD. No statistically significant differences were observed between the two groups on noun and verb comprehension (see Table 7.2). Also, effect sizes (Hedge's g) were estimated for noun and verb naming performance. A medium effect size was found for difference in noun naming ($g=-0.68$) and a large effect size ($g=-0.98$) for the difference in verb naming. The overall results on the GOAT between the two groups are graphically depicted in a line graph below (see figure 7.2).

Table 7.2: Mean percentage correct on noun and verb naming and comprehension for the PD and healthy control groups across subtests of the GOAT.

Variable name	PD(n=24)	HC(n=15)	Sign
Instrumental nouns+ name relation	78% (0,08)	80% (0,12)	0,539
Instrumental nouns - name relation	82% (0,09)	90% (0,05)	0,01
No instrumental nouns	89% (0,11)	96% (0,05)	0,037
Instrumental verbs-name relation	79% (0,12)	86% (0,12)	0,086
Instrumental verbs+ name relation	74% (0,16)	88% (0,09)	0,005
Non-instrumental verbs	67% (0,14)	75% (0,11)	0,076
Total noun production	83% (0,08)	88% (0,07)	0,039*
Total verb production	74% (0,11)	83% (0,07)	0,004*
Total noun comprehension	100%	100%	
Total verb comprehension	99% (0,03)	100% (0,01)	0,068

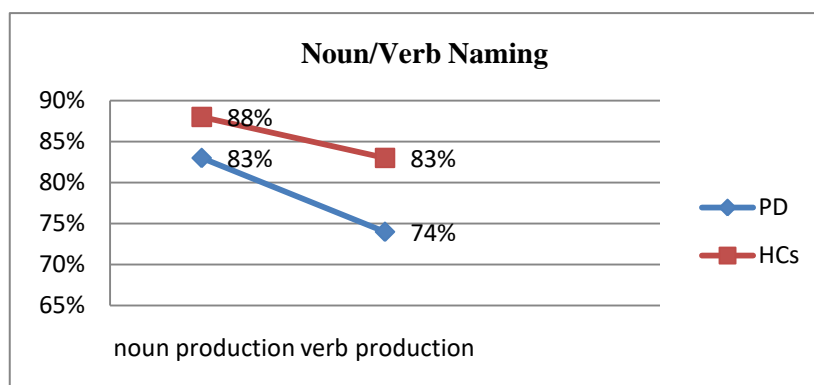


Figure 7.2: Overall performance on the GOAT between the PD group and HCs for single word noun and verb production.

Repeated measures ANOVA was performed to determine whether there is a significant difference between the three different types of verbs: (1) instrumental verbs without a name relation (IV-NR) vs. (2) instrumental verbs with a name relation (IV+NR) vs.(3) non-instrumental verbs (NIV) (see table 7.3). The ANOVA test revealed that there are statistically significant differences between the three groups ($F=7.312$, $p\text{-value}=0.004$).

Table 7.3: Pairwise Comparisons between the three types of verbs

		Mean Difference	Std. Error	Sig. ^c	95% Confidence Interval for Difference ^c	
					Lower Bound	Upper Bound
IV-NR	V+NR	.049	.033	.440	-.035	.134
	NIV	.115*	.021	.000	.061	.169
IV+NR	IV-NR	-.049	.033	.440	-.134	.035
	NIV	.066	.035	.218	-.025	.156
NIV	IV-NR	-.115*	.021	.000	-.169	-.061
	IV+NR	-.066	.035	.218	-.156	.025

Key: IV-NR= non-name related instrumental verb; IV+NR= name-related instrumental verbs; NIV= non-instrumental verbs; significantly different = $p. \leq 05$.

From the pairwise comparisons, the difference between the non-name related instrumental verbs vs.name-related instrumental verbs and name-related instrumental verbs vs. non-instrumental verbs does not differ, while a significant difference between the non-name related instrumental verbs and non-instrumental verbs revealed a statistically significant difference.

7.4 Quantitative and qualitative analysis of naming error types

An additional quantitative and qualitative analysis of error types was conducted. The coding system that was utilized was based on that proposed by Mitchum, Ritgert, Sandson, & Berndt (1990) (see Table 7.3).

Table 7.4: Error type definitions

Error	Definition /example
Correct	a) target e.g., "bicycle"(response) b) acceptable synonym e.g., "bicycle" (target) → "bike" (response) c) self-corrected response e.g., "bicycle" (target) → "a motorcycle, I mean bicycle" (response)
Semantic	a) coordinate or associate errors, e.g., "strawberry" (target)→ "banana" (response); "cheese" (target)→ "mouse" (response) b) super or subordinate, errors e.g. , "elephant" (target)→ "animal" (response) c) semantic description/circumlocution, e.g., "ball" (target)→ "kids play with it" (response)
Visual	a) misperception of the target word, e.g., "drum" (target) → "can" (response) b) apparent lack of recognition of the stimulus despite evidence that the item is familiar
Phonological	Errors that have at least 50% of the phonemes in common with the target word

The qualitative analysis revealed that semantic errors were the most frequent error type for the PD group for both grammatical categories and the second most frequent error was semantic descriptions/circumlocutions (see Table7.4).

Table 7.5: Error analysis for verb and noun naming for the PD group

Error types	Verb naming (%)	Noun naming (%)
Semantic errors	75%	65%
Semantic Circumlocution	16%	15%
Visual errors	3%	14%
No response	6%	6%

7.5 Performance on the repetition test and the idiom-metaphor processing task

A significant difference between the PD group and HCs was observed on the TIM i.e., metaphor/idiom production ($t=-2.451$, $p=0.019$) and on metaphor/idiom comprehension ($U=81.000$, $p=0.004$) (see table 7.5). No significant difference between the PD group and HCs was observed on sentence repetition test (see table 7.6).

Table 7.5: Mean percentage correct for group performance on the TIM

Variable	PD	HCS	Sig.
TIM Production	75 %	87 %	p=.019
TIM Comprehension	85%	92 %	p=.004

Key: TIM: test of idioms and metaphors; all variables are reported as mean percentage.

Table 7.6: Mean percentage correct group performance on the Sentence Repetition Test

Sentence Type	PD	HC	Sig.
SVO	83% (0,23)	90% (0,16)	0,41
Negation	89% (0,15)	93% (0,15)	0,221
CLLD	79% (0,24)	80% (0,3)	0,672
Coordination	97% (0,11)	93%(0,15)	0,32
Complement clauses	95 % (0,13)	87%(0,21)	0,196
Adverbials	93 % (0,14)	93% (0,2)	0,46
Wh-question	92 % (0,19)	97%(0,13)	0,27
Relative clauses	95 % (0,13)	98%(0,06)	0,37
Total Sentence Repetition Test	90%(0,1)	91%(0,13)	0,288 n.s

Key: SVO=subject-verb-object; CLLD: clitic left dislocation; all variables are reported as mean percentage.

Qualitative analysis of error types on the SRT

A qualitative analysis of error response patterns was performed for the PD and HC groups. PD group made more errors than HC group (see figure 7.3 and figure 7.4). Overall, the number of errors on content words was greater than function words.

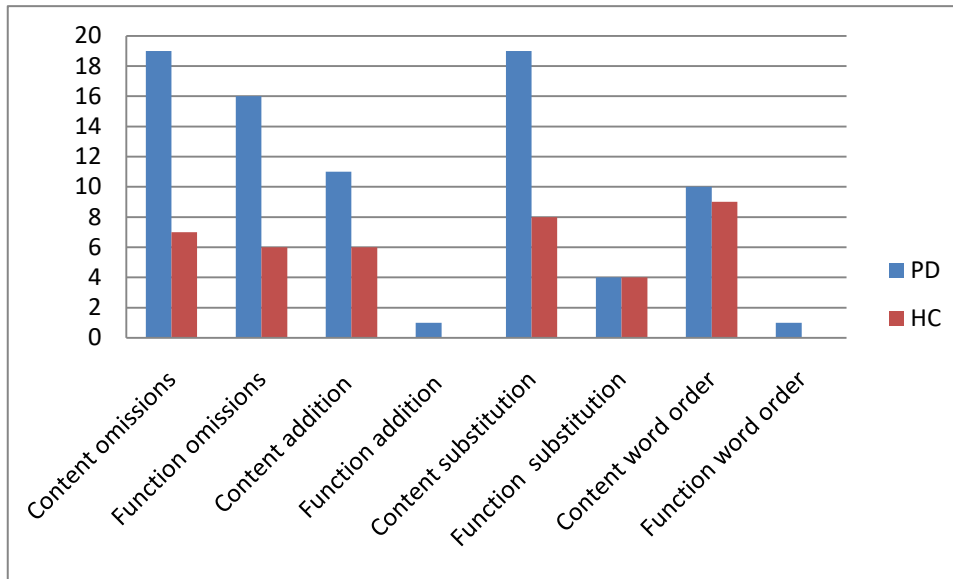


Figure 7.3: Types of errors produced for content and function words for both groups.

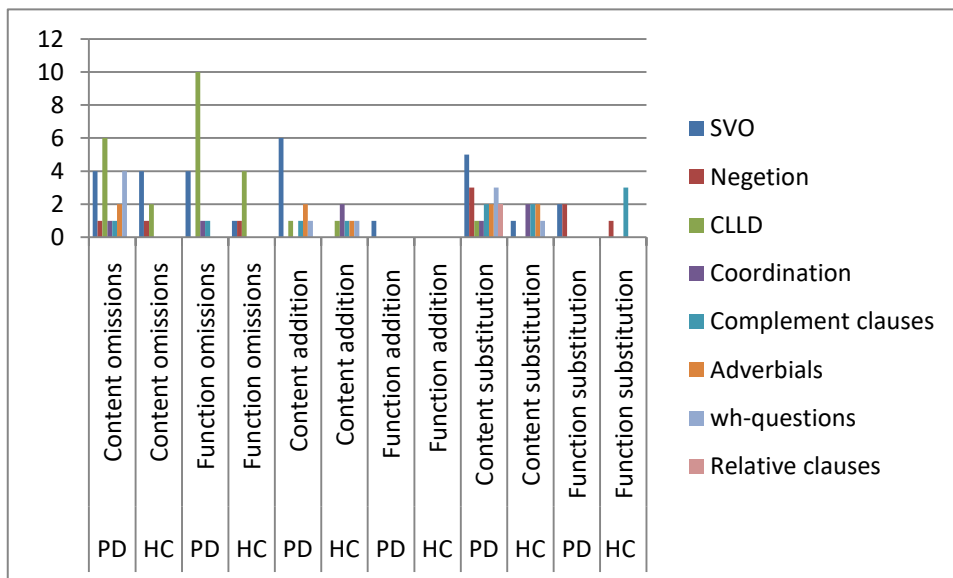


Figure 7.4: Types of errors produced for content and function words for every type of sentence.

7.6 Correlation and regression analyses

Correlation and regression analyses were performed to determine any associations between the linguistic abilities (naming, sentence repetition, idiomatic and metaphor processing) and the demographic characteristics, disease characteristics and non-linguistic cognitive abilities (attention span, working, semantic memory, executive functions, set switching). In addition to the above analyses, additional regression

analyses were performed to determine whether any of the psycholinguistic variables (i.e., word frequency, age of acquisition, imageability, picture complexity, number of phonemes) contributed to the naming accuracy.

7.6.1 Correlation analyses

Correlation analyses were calculated between the linguistic and the non-linguistic cognitive abilities (see table 7.7). Noun production was positively correlated with general cognitive functioning (MMSE) ($r=.460, p=.024$) and negatively correlated with age ($r=-.592, p=.001$) and with motor disability as measured by the UPDRS scale ($r=-.492, p=.015$). On the other hand, verb production was negatively correlated with age ($r=-.474, p=.19$) and positively correlated with the MMSE ($r=.486, p=.016$). Both noun ($r=.460, p=.024$) and verb ($r=.486, p=.016$) production were positively correlated with general cognitive functioning as measured by the MMSE.

Regarding the correlations between noun and verb naming and non-linguistic cognitive functions the results were as follows: noun production was negatively correlated with both TMT-A ($r=-.664, p=.000$) and TMT-B ($r=-.681, p=.000$) and positively correlated with semantic fluency ($r=.696, p=.000$) and phonemic fluency ($r=.483, p=.017$).

Similarly, verb production was negatively correlated with both TMT-A ($r=-.564, p=.004$) and TMT-B ($r=-.568, p=.004$) and positively correlated with semantic fluency ($r=.474, p=.019$).

Regarding the idiomatic and metaphor processing ability, production was positively correlated with DSB ($r=.536, p=.007$) and negatively correlated with TMT-B ($r=-.504, p=.012$). Comprehension was positively correlated with DSB ($r=.463^* p=.023$) and negatively correlated with TMT-B ($r=-.468^*, p=.021$) for the PD group.

Table 7.7: Correlation analyses between the linguistic and non-linguistic cognitive abilities

	Noun Production	Verb Production	Metaphor Comprehension	Metaphor Production	Sentence Repetition Test
DSF	r=.089,p=.679	r=.100,p=.642	r=-.130, p=.545	r=.075,p=.728	r=.411, p=.046**
DSB	r=.120,p=.578	r=-.221, p=.300	r=.463,p=.023*	r=.536, p=.007**	r=.462, p=.023**
TMT-A	r=-.664, p=.000**	r=-.564, p=.004**	r=-.355,p=.089	r=-.204, p=.338	r=-.228, p=.284
TMT-B	r=-.681, p=.000**	r=-.568, p=.004**	r=-.468, p=.021*	r=-.504, p=.012*	r=.670,p=.000**
SF	r=.696, p=.000**	r=.474, p=.019**	r=.353,p=.091	r=.388,p=.061	r=.312,p=.138
PS	r=.483, p=.017**	r=.195, p=.362	r=.366, p=.079	r=.389,p=.060	r=.268,p=.205

Key: DSF: Digit Span Forward, DSB: Digit Span Backward, TMT-A: Trail Making Test -A, TMT-B: Trail Making Test-B, SF: semantic fluency, PS: phonemic fluency * Correlation is significant at the 0.05 level, **Correlation is significantly different at the 0.01 level

7.6.2 Regression Analysis

In addition to the correlation analyses, stepwise regression analyses were performed to determine which of the demographic, clinical, neuropsychological variables predicted performance on the noun and verb naming task (GOAT). Specifically, the covariates entered for each dependent variable were the UPDRS score, the H&Y score, disease duration DSF, DSB value, TMT score and verbal fluency results. The variables that were finally selected for the stepwise regression analysis for noun naming were the semantic fluency scores, TMT-A scores, and chronological age. The percentage of variation (adjusted R square) of noun production performance that is explained by the regressors of the final model is 69.7 %. The final model of the stepwise analysis was statistically significant ($F=18.649, df1=3, df2=20, p\text{-value} < 0.001$). Overall, semantic fluency has a positive effect on noun production while TMT-A has a negative effect on noun naming performance.

The variables that were finally selected for the stepwise regression analysis for verb naming were the DSB and the TMT-B score. The percentage of variation (adjusted R square) of the verb production that is explained by the regressors of the final model is 52.2 %. The final model of the stepwise analysis was statistically significant

($F=13.583, df1=2, df2=21, p\text{-value}=0.00$). Both the TMT-B and the DSB have negative effect on verb naming accuracy

TABLE 7.8: Contribution of demographic, clinical and neuropsychological variables on naming performance in PD group

Word type	Beta	<i>t</i>	<i>Sig</i>
	$R^2=.564,$	$Adj.R^2=.522$	$p=.000$
Verb			
TMT-B	-804	-5.158	.000
DSB	-3	-2.659	.015
	$R^2=.737$	$Adj.R^2=.697$	$p=.000$
Noun			
SF	.420	3.225	.004
TMT-A	-389	-2.937	.008

Key: TMT-B: trail making test part B; DSB: digit span backwards; SF: semantic fluency; significance level at 0.05.

7.8 Contribution of psycholinguistic variables on naming performance

Additional multiple regression analyses were performed to determine whether the psycholinguistic variables that influence picture naming accuracy contributed to action and object naming performance for the PD group.

The psycholinguistic variables that were included as covariates were lemma frequency, syllable length, age of acquisition, imageability and picture complexity ratings. The description of the procedure followed in addition to the mean values of psycholinguistic variables for nouns and verbs were taken from Kambanaros (2003). The frequencies for nouns and verbs were based on the printed word frequency for Greek (Hatzigeorgiou et al., 2000) as reported in published work by Kambanaros and colleagues (2010;2016).

Statistical analysis (see Table 7.9) revealed no significant difference between verb and noun word frequencies ($z = -1.264, p = .443$), verb and noun syllable length ($z = -1.296, p = .264$), number of phonemes ($z = -.790, p = .429$), and rated age of acquisition ($z = -1.168, p = .243$). However, there was a significant difference for word

imageability ($z = -2.978$, $p = .003$) and picture complexity ($z = -2.331$, $p = 0.20$) with higher ratings for nouns (i.e., more imageable and less visually complex) compared to verbs.

The ratings of age of acquisition (AoA) were based on the procedure proposed by Gilhooly and Logie (1980). Twenty neurotypical participants were asked to provide an estimation of the chronological age they first encountered each of the target words (verb/noun), on a seven-point scale (with 1 representing 0–2 years to 7 representing 13 years of age and older). Similarly, the ratings of word imageability were based on the procedure proposed by Paivio, Yuille, & Madigan (1968). A different sample of twenty neurotypical participants were asked to rate the ease with which they could arouse a mental image of the concept (verb/noun) referred to by the (written) word. Ratings were performed on an eight-point scale (with 0 = impossible, up to 7 = most imageable). The rating of picture complexity was based on the procedure described by Snodgrass, & Vanderwart (1980). A further twenty neurotypical participants were asked to rate on a seven-point scale the ease with which they could recognize the target (noun/verb) in the picture (with 1 = least easily, up to 7 = most easily). AoA, imageability, and picture complexity scores were determined for every word by averaging ratings, where different groups of healthy subjects were used as raters for each variable. The mean values of characteristics for nouns and verbs are reported in Table 7.8.

Also, the word frequency of the three different verb types was calculated (Hatzigeorgiou et al., 2000). The word frequency between instrumental verbs without a name relation to the noun (IV-NR) and instrumental verbs with a name relation to the noun (IV+NR) was not significantly different according to the corrected level of significance ($z = -2.027$, $p = .043$). However, non-instrumental verbs (NIV) were significantly higher on word frequency than IV-NR ($z = -3.012$, $p = .003$) and IV+NR ($z = -3.920$, $p < .001$). The difference for age of acquisition was not significant between IV-NR and IV+NR ($z = -1.749$, $p = .080$) or between IV-NR and NIV ($z = -.851$, $p = .395$). IV+NR verbs appear to have a significantly higher age of acquisition than NIV ($z = -2.412$, $p = .016$). Neither the ratings of imageability nor picture complexity were significantly different between the three verb categories.

Table 7.8: Mean values (SD) of psycholinguistic characteristics for noun and verb pictures of GOAT

Picture type	Word frequency	Syllable length	Number of phonemes	AoA (in years)	Word imageability	Picture complexity
Nouns	40.91	2.88 (.803)	6.50 (1.6)	2.98 (.76)	6.49 (.49)	6.49 (.28)
Verbs	40.11	2.95 (.731)	6.13 (1.3)	2.82 (.58)	6.42 (.16)	6.16 (.67)
Mann-Whitney test						
z-values	-1.264	-1.296	-.790	-1.168	-2.978	-2.331
p-values	.443	.264	.429	.243	.003*	.020*

Key: GOAT: Greek Object and Action Test; AoA=age of acquisition; standard deviation in parentheses; significantly different; significance level at 0.05

Table 7.9: Multiple regression analyses: contributions of psycholinguistic variables on GOAT naming accuracy in the PD group

Word type (errors)	Beta	<i>t</i>	<i>Sig</i>
Verb			
Age of acquisition	.220	1.425	.163
Imageability	-.048	-.297	.768
Word Frequency	.130	.957	.345
Picture Complexity	-.617	-4.597	.000*
Number of phonemes	.094	.728	.417
Noun			
Age of acquisition	.035	.181	.857
Imageability	-.104	-.609	.546
Word Frequency	-.184	-1.145	.260
Picture Complexity	-.508	-3.160	.003*
Number of phonemes	.094	.595	.556

Key: significance level at .05

Chapter 8: Discussion

In this chapter, the research findings are discussed considering the current evidence in the literature on neurocognitive and linguistic performance in individuals diagnosed with PD. The discussion is organized according to the aims of the study. First, the findings regarding the neurocognitive tasks will be discussed followed by the findings on linguistic performance.

The goal of this study was to explore the cognitive-linguistic profile of Greek-speaking participants with PD. To the best of my knowledge, this is the first study that explores the relationship between neurocognitive performance and linguistic abilities in Greek-speaking individuals with PD. A further important characteristic of the present study is that involves a language that is morphologically complex.

To explore the questions of this study, a battery of neurocognitive and three different language tasks were administered. The neurocognitive tasks tapped into attention span, working memory, set switching and verbal fluency. The language tasks included a noun and verb retrieval task using a visual confrontation naming task (lexical-semantic level), a task of sentence processing using a sentence repetition task (morphosyntactic level) and a task of idiomatic and metaphor language processing (high-level language).

To investigate the hypotheses of the study, a cross-sectional study design was chosen. All participants were native Greek-speakers, and the cognitive and language assessments were carried out in Greek by a native-Greek researcher. The results were derived from the direct comparisons of the two groups, participants with PD and healthy neurotypical controls, matched on demographic variables on different neurocognitive and linguistic tasks. Overall, the findings revealed that the PD group performed significantly worse on tasks of executive functions in addition to lexical-semantic and high-level language tasks.

8.1 Cognitive functions in PD

The first aim was to define the cognitive profile of the PD group. To address this goal, the cognitive functions of the PD group were compared to the cognitive abilities of healthy controls. Several neuropsychological measures were administered to assess the cognitive abilities of individuals with PD. These included measures of attention span,

verbal working memory, cognitive flexibility, and set-switching ability are all sensitive to frontal lobe dysfunction. The current body of evidence suggests that non-demented individuals with PD present impairment in these neurocognitive domains (Dirnberger & Jahanshahi, 2013) and that these measures are sensitive to disruption of the frontal-striatal network (Kehagia et al., 2010).

The analysis of the neurocognitive measures revealed that there was a significant difference between the PD group and the healthy participants on tasks sensitive to frontal lobe dysfunction. Specifically, the PD group performed significantly lower on both TMT measures (parts A and B) as well as on the phonemic fluency task. However, no statistically significant difference was observed on tasks of attention span (DSF), the working memory task (DSB) or on the measures of semantic fluency.

Executive dysfunction frequently occurs early in the course of PD. Executive dysfunction is associated with disruption of the fronto-striatal network (Lewis, Dove, Robbins, Barker, & Owen, 2003). It is also associated with reduced subcortical gray and white matter as well as fewer connections from the bilateral dorsolateral-prefrontal cortex to the caudate nucleus (Crowley et al., 2021). According to the findings, as expected, the PD group presented behaviorally with cortical frontal type of deficits specifically related to executive functions (TMT-B and phonemic fluency) compared to neurotypical adults.

8.1.1 Verbal fluency in PD

Of clinical significance are the findings of the PD group on verbal fluency abilities. According to the results, the two groups had significant performance differences only on the phonemic fluency task and no difference on the semantic fluency tasks. This finding is in contrast to the results of an early meta-analytic study that included two thousand six hundred forty-four (2,644) PD participants from sixty-eight studies that suggested that the individuals with PD demonstrated greater semantic fluency than phonemic fluency deficits (Henry & Crawford, 2004). Accordingly, the authors interpreted this difference on the basis that both verbal fluency tasks require effortful retrieval processes, but that semantic fluency may be more demanding on cognitive processing.

Even though it is a frequent finding in the literature that PD individuals have deficient semantic fluency skills and not phonemic fluency, indeed there are several studies suggesting that the difficulty in phonemic fluency is not uncommon in PD offering support to the current results. Specifically, a number of early studies have supported that individuals with PD may have more pronounced deficits in phonemic fluency compared to semantic deficits (Azuma et al., 1997; Flowers, Robertson, & Sheridan, 1995). In particular, some evidence from previous work has shown that the deficits may be only in semantic fluency (Auriacombe et al., 1993) whereas other studies revealed deficits in both PF and SF (Suhr & Jones, 1998). Other studies have reported no differences between PD and neurotypical controls on both verbal fluency tasks (Hanley, Dewick, Davies, Playfer, & Turnbull, 1990).

This reported difference might be attributed to distinct underlying mechanisms of the two fluency tasks. Semantic fluency is dependent on the integrity of semantic memory whereas phonemic fluency is dependent on the integrity of executive functions (Gordon et al., 2018). Therefore, it can be concluded that the deficits may not be attributed to disorders in semantic memory per se and as such to the lesions of temporal areas.

Greater difficulty with phonemic fluency compared to semantic fluency is indicative of executive dysfunction. Clinical evidence suggests that the executive deficits can frequently occur in non-demented individual with PD in the early stages and may be the first symptom of cognitive impairment in this population. This reflects the disruption of cortico-basal ganglia circuitry (Sawamoto et al., 2008) and front-striatal dysfunction.

PD participants in this study performed worse on phonemic compared to semantic fluency. Some earlier studies indicate that individuals with PD show phonemic fluency deficits because of the critical role that executive functions play in the phonemic task. However, other studies have found the opposite pattern in verbal fluency tasks. One possible explanation for the results found in the study is that the PD group has relatively preserved semantic processing skills as evidenced by intact performance on comprehension tasks. Considering the findings of previous studies presented earlier, this finding is not uncommon in PD.

8.1.2 Set switching abilities in PD

The results also revealed that the PD group performed significantly different to healthy controls on both parts of the TMT. This finding is in line with current research that purports that the performance of PD groups on the task of TMT is deficient (Kourtidou, Kasselimis, Potagas, & Zalonis, 2015). In particular, the deficient performance on set-shifting task and especially on TMT part B is consistent with earlier studies (Cools, Barker, Sahakian, & Robbins, 2001; Dubois, 1997; Hietanen & Teräväinen, 1986).

TMT performance is dependent on the integrity of executive functions and is susceptible to frontal lobe disruption (Stuss et al., 2001) since it involves the activation of frontal and parietal cerebral areas (Pa et al., 2010). It also requires several cognitive processes related to executive functions such as attention, processing speed, set-shifting and working memory (Sánchez-Cubillo et al., 2009).

Even though neuroimaging data were not available for PD participants, the assumption is that the cognitive profile is related to cerebral disruption of anterior brain areas such as frontal lobes. This is consistent with the dual syndrome hypothesis (Kehayia, Barker & Robbins, 2013). According to this model several individuals with PD present underlying neuropathology that is mainly characterized by disruption of the frontal-striatal neural networks and is described with the term “dysexecutive syndrome”. Based on the above, it can be claimed that cortical atrophy may be more widespread in the anterior cerebral areas such as in the frontal lobes (Baldo et al., 2003).

Frontal lobe function is associated with executive functions and all related cognitive tasks such as the DSB, TMT and verbal fluency (Yuan & Naftali, 2014). In addition, the set-switching deficits in PD have been linked to prefrontal cortex pathology (Monchi, Pertidis, Doyon, Postume, Worsley & Dagher, 2004). Overall, the PD group presented with dysexecutive symptoms and no evidence of reduced working memory capacity or semantic deficits.

8.2 Noun and verb naming abilities in PD

The second aim of the study was to investigate the noun and verb retrieval ability in individuals with PD as a measure of low-level language abilities tapping into lexical-semantic processing. Overall, the results showed that the PD group had difficulty naming both nouns (objects) and verbs (actions) compared to healthy controls.

Moreover, PD participants showed greater impairment of verb retrieval ability compared to noun retrieval ability. These findings are consistent with the results of earlier studies that have investigated noun and verb differences in lexical retrieval/naming in PD participants (Bartella et al., 2002; Cotelli et al., 2007; Salamzou-Silva et al., 2017; Silveri et al., 2012).

Single word processing ability was evaluated by utilizing the tasks of visual confrontation naming as well as comprehension skills via an auditory word-picture matching task. In order to investigate lexical retrieval abilities, the Greek Object and Action Test (GOAT) was administered. The GOAT is a picture-based assessment that has been used in several clinical studies concerning different clinical populations of Greek-speaking participants with various neuropathologies (e.g., stroke-induced aphasia, Multiple Sclerosis, Schizophrenia). Both categories of words were matched on several psycholinguistic variables such as lexical frequency, age of acquisition, syllable length, imageability, and picture complexity in the Greek language (Kambanaros, 2003). In addition to the assessment of noun and verb naming ability, further analyses were conducted regarding first, the effect of verb instrumentality and name relation on naming; second, the naming error patterns; third, the impact of psycholinguistic variables on naming ability; and finally, the impact of neurocognitive variables on naming ability.

8.2.1 Noun and verb comprehension in PD

The comprehension skills of PD participants were assessed at the single word level. The findings showed that the individuals with PD had no specific noun or verb impairments comprehending single words.

The assessment of noun verb comprehension ability via an auditory word-picture matching task is one advantage of the present study. It is noteworthy that most of the published research concerning single word production in PD so far lacks the inclusion of tasks of assessment of comprehension abilities for nouns and verbs (Cotelli et al., 2017). It could be assumed that comprehension abilities at single word level are intact or largely preserved in published studies but without testing this hypothesis there is still the possibility that this might not always be the case. According to the present findings, the individuals with PD did not have difficulty comprehending the same set of nouns

and verbs used in the production task. The PD group's normal performance on receptive language skills reveals comprehension skills to be intact at the single word level.

8.2.2 Noun and verb production

The findings showed the PD group had significant retrieval impairment for actions and objects compared to healthy controls. Additionally, verb production was significantly worse in the PD group than noun retrieval. The medium size effect for noun naming ($g = -0.68$) and the large size for verb naming ($g = -0.98$) emphasizes this finding.

8.2.2.1 Effect of instrumentality

The present study aimed to explore the impact of the lexical-semantic variable of instrumentality and the lexical-phonologic variable of name relation on verb retrieval ability. In particular, the retrieval ability of three different types of nouns and verbs was explored. The three categories of nouns were (i) name-related instrumental nouns; (ii) non-name-related instrumental nouns and (iii) non-instrumental nouns. On the other hand, the three categories of verbs were (i) the name-related instrumental verbs; (ii) the non-name-related instrumental verbs and (iii) the non-instrumental verbs. The comparison of noun naming performance among the three different categories revealed that individuals with PD had significant difficulty naming instrumental nouns compared to non-instrumental nouns.

The comparison of verb naming performance among the three different verb categories revealed that instrumentality facilitates verb retrieval for the PD group. In particular, the individuals with PD had significantly better performance naming instrumental verbs compared to non-instrumental verbs. No significant difference was observed between the name-related and non-name-related verbs. Therefore, the findings show that the factor of name relation does not have an impact on verb retrieval ability in individuals with PD whereas the factor of instrumentality facilitates the verb retrieval ability.

Two possible accounts might explain the facilitatory role of instrumentality in verb naming in this case. The first account is related to the neural substrate expansion responsible for the lexical retrieval of instrumental and non-instrumental verbs.

Malyutina et al. (2016) utilized functional Magnetic Resonance Imaging to explore the neural underpinnings of instrumental verbs in a group of healthy young participants.

The authors compared the neural activation corresponding to the retrieval of

instrumental and non-instrumental verbs. They performed a region of interest (ROI) analysis that revealed that the non-instrumental verbs activated a wider neural circuitry that includes bilateral frontal and parietal cerebral areas and left-lateralized inferior and middle temporal and occipital cortex. The activation of frontal brain areas also included the pars triangularis of the inferior frontal associated with non-instrumental verb retrieval. The authors claimed that non-instrumental verbs engage a more extensive neural network as opposed to instrumental verbs. This finding could explain the better performance on instrumental verb naming in that PD participants needed to activate a less extensive neural network during the retrieval of instrumental verbs. Subsequently, given that less cerebral areas are required for lexical retrieval of instrumental verbs might explain this pattern.

A second possible explanation for the positive effect of instrumentality is based on the semantic complexity theory (Breedin, Saffran, & Schwartz, 1998). According to this account, the verbs can be divided in semantically complex/heavy verbs and semantically simpler/light verbs. This feature is expected to be a potential variable that may affect the verb retrieval either with a positive or a negative effect. The semantically complex/heavy verbs due to their additional semantic features are considered to be more specific than the semantically simpler/light verbs i.e., *run vs go*, *wipe vs clean*. In the present study, the instrumental verbs are considered semantically complex and more specific compared to non-instrumental verbs. Based on the above theoretical basis, the instrumentality's facilitating effect can be explained by the effect of semantic complexity and therefore it can be assumed that the verb retrieval in PD can be influenced by the semantic properties of the verb.

A further lexical characteristic of instrumental verbs that may contribute to this pattern is that they are considered more specific than non-instrumental verbs. The presence of the tool in their conceptual representation reduces the number of actions that may be completed by a specific tool. Therefore, instrumental verbs are associated with fewer alternative meanings compared to non-instrumental verbs during the process of lexical selection (Kambanaros, 2003).

The lexical-semantic factor of instrumentality adds additional complexity to the verb and is considered to be a facilitating variable in the retrieval process in different neuropathologies (Jonkers & Bastiaanse, 2007; Sloot & Jonkers, 2011). The role of

instrumentality has been explored in a number of published studies with different clinical populations such as stroke-induced aphasia, Alzheimer's disease, Multiple sclerosis, and Schizophrenia (Kambanaros, Messinis, Georgiou, & Papathanasopoulos, 2010; Kambanaros, Messinis, Nasios, Nousia, & Papathanasopoulos, 2017; Sloot & Jonkers, 2011). This is the first research that explores the effect of instrumentality on the naming ability in a neurodegenerative motor disorder and specifically in PD that it is mainly characterized by disruption of the fronto-striatal circuitry (Kehagia et al., 2010). The conceptual representation of instrumental verbs includes the information about the tool that is required in order for the actor to execute the action.

Interestingly comparing the results from other progressive neurodegenerative disorders, Sloot & Jonkers (2011) explored the effect of instrumentality on the naming ability of individuals with Alzheimer's Disease (AD). According to their results, instrumentality had a positive effect on verb retrieval ability. The opposite pattern was found by Kambanaros et al. (2017) in a study on naming ability in individuals with Multiple Sclerosis (MS). The results revealed that instrumental verbs were more difficult to retrieve than non-instrumental verbs. Name-related instrumental verbs were also easier to retrieve than non-name-related instrumental verbs but no significant difference was found between instrumental and non-instrumental verb retrieval.

However, the results of the present study contradict the results from previous studies that have explored the role of the motor related semantic properties of verbs in individuals with PD (Bocanegra et al., 2017; Herrera et al., 2012; Salamzo-Silva et al., 2017). These studies have suggested that the verbs with high motor content might be expected to be more difficult to retrieve for the individuals with PD compared to verbs with low motor content. Taking into account the above point, one could predict that instrumental verbs would be more difficult to retrieve compared to non-instrumental since they contain a motor content. However, this was not the case in the present research.

The present research is the first study that explored the effect of the semantic factor of instrumentality in a motor disorder. Other semantic factors related to motor elements of action verbs that have been explored so far in the literature are the motor content of verbs and manipulability (Bocanegra et al., 2017; Cotelli et al., 2007; Herrera et al.,

2012). Based on the findings it can be postulated that the factor of instrumentality facilitates verb retrieval ability in individuals with PD.

Another explanation can be based on Dell's interactive-activation lexical model (Dell, 1986). According to this model, the retrieval of an instrumental verb will co-activate both lemmas, the verb's lemma, and the noun's lemma (see figure 8.1). During the picture-naming of an instrumental verb, the participant is exposed to visual stimuli of both words, the object (i.e., the required instrument for the action) and the action. It can be assumed that simultaneous retrieval of noun's lemma in the case of instrumental verbs may possibly enhance the verb retrieval performance. Previous studies have proposed the same hypothesis for the facilitatory role of instrumentality in verb retrieval (Bastiaanse, 1991; Jonkers & Bastiaanse, 2007).

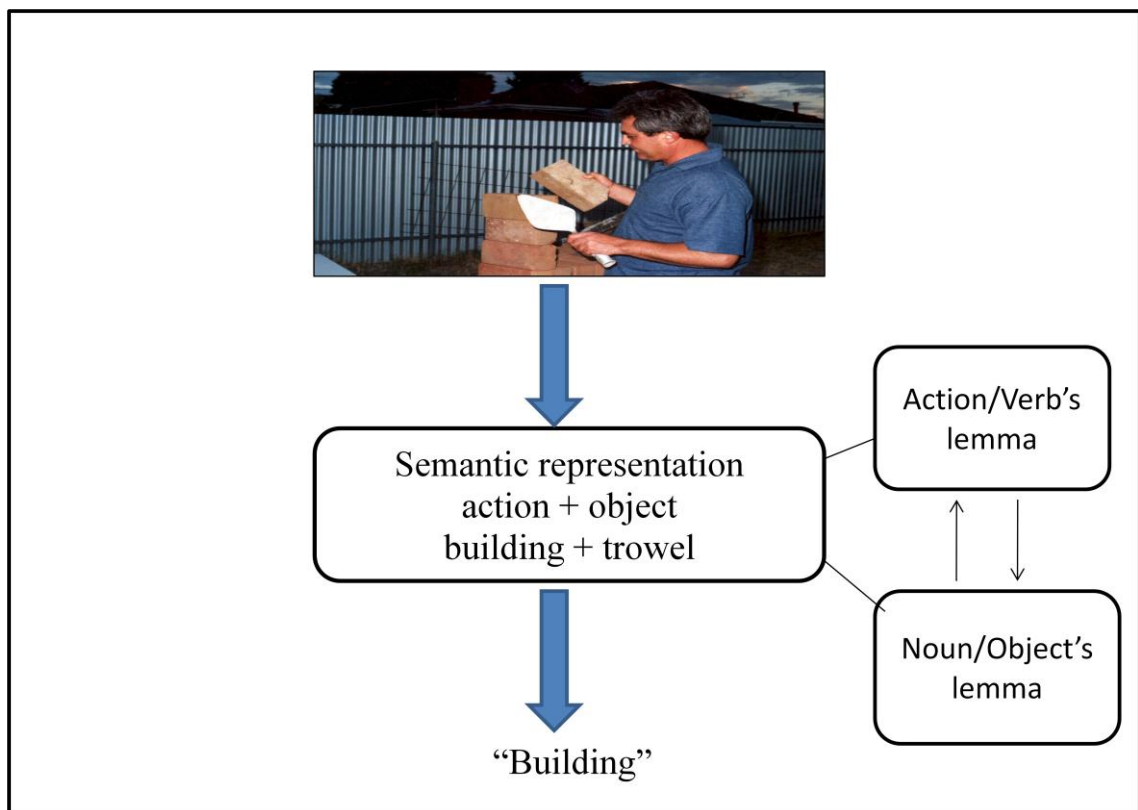


Figure 8.1: Semantic representation of the instrumental verb 'building'

However, a reasonable question that arises comes from the Embodied Cognition theory (Meteyard et al., 2012) that explains the action-verb retrieval deficits in PD. The use of an instrument that is a tool, during the specific action performance denotes at least some degree of motor content. In this study the instrumental verbs that were used e.g., 'drawing' that involves the representation of a "pencil" (ζωγραφίζω (to draw)-μολύβι

(pencil), "hammering" contains (καρφώνω (to hammer)-σφυρί-hammer), "stirring" (to stir=ανακατεύει, "building" (to build=κτιζώ-μυστήρι) contain some degree of motor content. These verbs are not name related in Greek so the possibility that name relation might have facilitated the verb retrieval ability can be excluded. Based on the related published literature (Herrera et al., 2012) one would reasonably expect that the motor content of the instrument verbs due to the obligatory use of the instrument would reduce the retrieval accuracy and there should either be no difference between instrumental and non-instrumental verbs or instrumental more difficult to retrieve than non-instrumental.

In the present study, instrumentality was defined according to criterion whether the action-verb requires an instrument/tool to carry out the action. The degree of motor content of the verb was not estimated as in the above-mentioned studies. It could be assumed that the concept of instrument/tool indicates that there is a general motion element as part of the conceptual representation of the verb but the degree of the motor content could be a different and very specific semantic variable that may influence the naming accuracy.

8.2.2.2 Qualitative error analysis of noun-verb naming in PD

The findings revealed most of the naming errors to be semantic in nature. This indicates that the naming disorder may arise during the stage of semantic processing of the words. This stage includes the analysis of semantic features of the target word and the differentiation between the target words with other words that share the same semantic characteristics (Mitchum et al., 1990). The pattern of semantic errors in association with intact comprehension skills indicates that the lexical representation of the word is largely preserved and therefore most likely that the naming difficulty arises during the access of the conceptual representation of the word (Cloutman et al., 2009). This phenomenon is characterized as anomia or word-finding deficits.

To this end, Silveri et al. (2012) found that the majority of the error types in verb naming were omissions. Grammatical, semantic, and visual errors were less frequent. In a different study, Salmaz-Silva et al. (2017) found that the naming errors were mainly semantic and specifically semantic circumlocutions. They interpreted the use of a more generic verb as a compensatory strategy to overcome the inability to access a more

complex verb (e.g., "to make bye" instead of "to wave" or "to look at the book" instead of "to study"). The findings of the current research lend support to this interpretation.

8.2.2.3 Effects of psycholinguistic variables on the naming process in PD

The third aim of the study was to explore the effect of several psycholinguistic variables on word retrieval ability.

The regression analyses revealed that the picture complexity (the amount of visual detail/intricacy in a picture) was a predictor for noun and verb name retrieval accuracy. There was no effect of the remaining psycholinguistic variables. Picture complexity has been found to be a predictor for naming performance for individuals with non-focal neuropathology such as Schizophrenia (Kambanaros et al., 2010) and Multiple Sclerosis (Kambanaros et al., 2017). Silveri et al. (2012) performed a correlation analysis between noun and verb naming with several psycholinguistic variables. They also found no correlation found between verb naming and any of the psycholinguistic variables only that noun naming was correlated with imageability. Overall, for this research only picture complexity was a predictor for successful lexical retrieval of verbs and nouns.

8.2.2.4 Effect of neurocognitive variables on naming performance in PD

The fourth aim was to investigate whether the non-linguistic cognitive variables predict naming performance. The regression analyses revealed that naming ability was predicted by executive functions. In particular, the performance on TMT-B and digit span backward predicted the verb naming accuracy. In contrast, semantic fluency and TMT-A predicted noun naming accuracy.

Regarding the association between the naming skills and the set-switching ability, data from neurotypical older healthy adults suggest that the set-shifting ability may be associated with the accuracy of noun and verb naming performance (Higby et al., 2019; Zeshu Shao, Roelofs, & Meyer, 2012). On the other hand, set-shifting deficits are a common deficit in PD (Cools et al., 2001; Kourtidou et al., 2015; Owen, 2004). This is in line with the previous findings of a positive correlation between verb production deficits with executive dysfunction in PD (Crescentini, Mondolo, Biasutti, & Shallice, 2008; Colman et al., 2009). Colman et al. (2009) suggested that the verb production difficulty was attributed to set switching deficits. The same association was found in the

present study. However, Bocanegra et al. (2015) did not find a correlational relationship between verb retrieval deficits and executive functions.

Moreover, the correlational relationship between verb retrieval and executive function can be supported by the neural circuits that support the two distinct cognitive functions that nevertheless share the same neural underpinnings. It is well known that verb retrieval is associated with frontal cortical circuits (Rofes & Miceli, 2014; Shapiro et al., 2005). Also, phonemic fluency skills are linked to the integrity of frontal lobes (Baldo, Schwartz, Wilkins, & Dronkers, 2006).

In a different line of studies, researchers have explored the correlation between executive functions and the action language processing ability in PD groups with mixed results. However, studies involving frontal cortical pathologies are in favor of this suggestion (Silveri & Ciccarelli, 2007). On the other hand, it is well known that executive dysfunction is very common in the early stages of the disease (Kehagia et al., 2012). It has been speculated in several research reports that the verb processing deficits are linked to disruption of fronto-striatal system (Bertella et al., 2003; Cotelli et al., 2007; Peran et al., 2003; Smith & Caplan, 2018).

In regards to the influence of other neurocognitive factors on naming ability, the results showed a moderate correlation between noun and verb naming and general cognitive functioning. Finally, the naming ability was not correlated with the severity of the motor symptoms of the PD group.

To summarize, the results from the present study suggest that the semantic complexity of instrumental verbs facilitates the retrieval process. Overall, the study's results suggested that the PD group exhibited executive dysfunction. Specifically, the participants with PD performed significantly worse than controls on TMT measures and on phonemic fluency as both tasks are dependent on the integrity of the frontal lobes.

8.2.2.4 Interpretation of naming deficits based on lexical models

Lexical models (Levelt, 1989) offer a theoretical framework for interpreting naming deficits. According to the findings, the participants with PD were able to comprehend verbs and nouns, indicating that lexical representations for both grammatical categories of words are intact at the conceptual–semantic level. This suggests that the locus of deficit in lexical processing is at the semantic system during the semantic processing of

the word. The observed error patterns in naming may offer insights about the locus of the breakdown. The production of semantic errors in naming tasks when word comprehension is intact indicates difficulty in activating the appropriate lemma (Levelt, 1989; Wilshire & Coslett, 2000). Research suggests that during the production of words that are semantically related to the intended word, the deficit occurs during the access of the word's semantic representation (Caramazza & Miozzo, 1997; Howard & Gatehouse, 2006; Levelt, 1989). Semantic errors may indicate an impairment in the activation of a different word that it is semantically related to target word e.g., 'dog'(target)→'cat'(response) (Caramazza & Miozzo, 1997; Howard & Gatehouse, 2006).

According to lexical model (Levelt et al., 1999, 2001) lemma retrieval (i.e., the abstract lexical representation of the word that includes grammatical and syntactic properties of the target lexical item), initially activates the lemmas of words with similar semantic characteristics (see figure 8.3). The individual must select the appropriate lemma that corresponds to target word. If this process of lemma selection is deficient, then another word will be selected that shares some semantic features with the target word. This will result in the production of a word that is semantically related to the target word (see figure 8.4). Based on Levelt's model and the four occasions that a semantic error may occur that mentioned earlier, it can be reasonably hypothesized that the semantic errors in PD group occur during the process retrieval of the related lemma.

Semantic errors may serve as an indication that the impairment is at semantic level. One plausible explanation for this specific word retrieval difficulty is that the individuals with PD retain the ability to access the lexical representation of word in the mental lexicon and specifically in the semantic memory but present retrieval deficits at a later stage post conceptual representation. This leads to the conclusion that nature of retrieval deficits are post semantic deficits at the level before the activation of the phonological properties of the word (Caramazza & Miozzo, 1997).

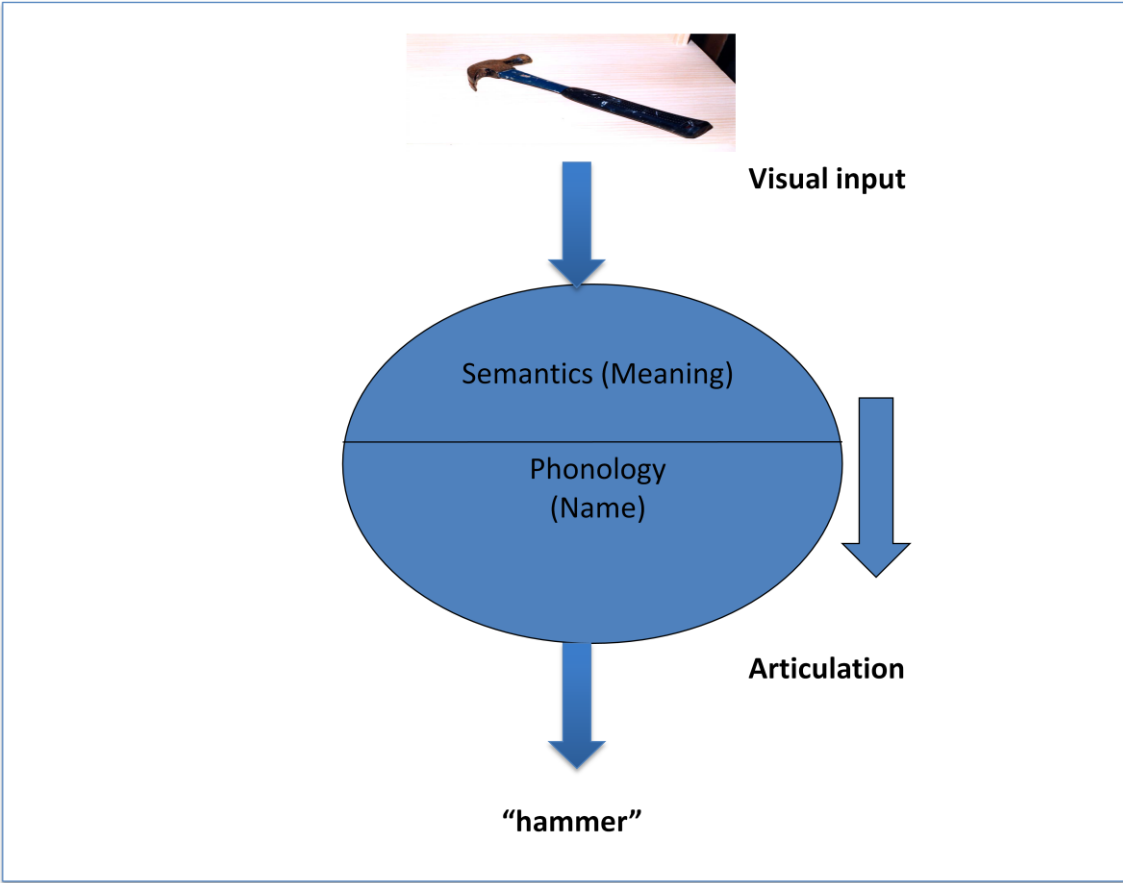


Figure 8.2: Naming of the noun “hammer”

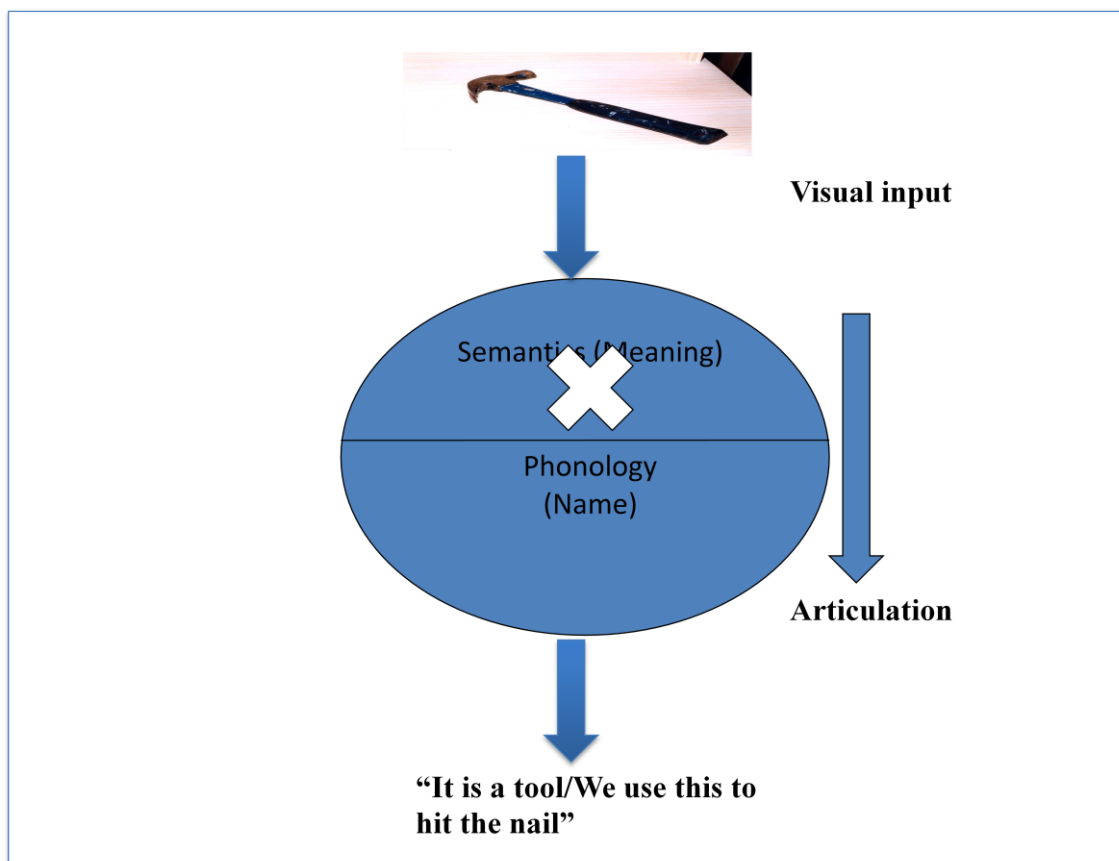


Figure 8.3: Semantic errors of naming of the noun “hammer”

8.3 Sentence Repetition abilities in PD

The fifth aim was to explore the performance of the PD group on a sentence processing task that incorporated morphosyntactic operations of varying complexity (Chondrogianni et al., 2013). The results revealed that the PD group was able to repeat syntactically simple sentences (e.g., subject-verb-object) and syntactically complex sentences (e.g., with negation, adverbials, wh-questions, relative clauses). This is an important point since repetition does not involve verbatim repetition of the surface representation of a sentence but requires also the deeper processing of the conceptual and syntactical representations of the words. In fact, during a sentence repetition task, the speaker needs to reconstruct the sentence using each lexical item of the sentence while maintaining it in short-term memory as well as processing the semantic information of the sentence (Lombardi & Potter, 1992; Potter & Lombardi, 1990). One reasonable explanation for the findings is that the individuals with PD exhibit intact morphosyntactic processing skills. This is in line with the results of earlier studies that

have explored the sentence repetition ability of PD groups on complex sentences (Berg et al., 2003).

However, in a different study, Troche & Altman (2012) utilized the task of sentence repetition of different syntactical structure. They included simple sentences with a prepositional phrase (e.g., ‘the passenger from the suburbs waited for the rain’), and complex sentences with a relative clause (e.g., the tornado that swept through the town destroyed several homes).

Sentence repetition ability was scored on three language dimensions a) fluency, whether the sentence is fluent or not; b) grammatically, whether the sentence is grammatically correct and c) completeness. A sentence should meet all three conditions in order to be complete and acceptable. The PD group produced a smaller number of acceptable sentences. Interestingly enough when the effects of cognitive ability were controlled, there were no longer a significant group difference between PD and control groups in performance on sentence repetition. Taking into account, the ability to repeat the specific syntactical structures may imply that the conceptual representation of these lexical items are well preserved (Lombardi & Potter, 1992; Potter & Lombardi, 1990).

Despite previous research suggesting that individuals with PD have difficulty comprehending complex sentences, the finding of no significant difference between the PD and healthy control groups on sentence repetition task in the present research could be explained by considering the possibility that the repetition of a sentence requires less computational resources than the sentence generation task. According to the model of sentence processing proposed by Bock & Levelt (2002), the sentence generation process consists of five stages: message level, functional level (lexical concept selection, assignment of grammatical and syntactic roles), positional level (set all the sentences elements in order), phonetic encoding, and articulatory planning. On the other hand, the sentence repetition task is regarded as less cognitively demanding task because it requires fewer cognitive processing stages. Based on the above model of sentence generation, Troche & Altman (2012) proposed that the sentence repetition task includes only the positional level, the phonetic encoding, and the articulatory planning but not the message or functional processing stage. The exclusion of this stage might have minimized the required computational resources for the repetition of a particular sentence.

Regarding the utility of sentence repetition tasks in exploring the syntactic processing skills, Small, Kemper, & Lyons (2000) argued that the difficulty with sentence repetition may be due to "sentence-internal" processes. They suggested that the computational demands of this task are not related to syntactic properties of the sentence. The authors also claimed that "sentence repetition engages not only lexical-semantic and syntactic processing but also sentential semantic processing (and, importantly, without requiring "post interpretive" processing)" (p.235).

The qualitative analysis of the errors revealed that the errors were more frequent on content words than function words. The main difference between these two categories of words is that content words provide semantic information whereas the function words contain grammatical information but both are necessary for the sentence formation.

In sum, a possible explanation for the findings might be that the PD group exhibited intact morphosyntactic processing abilities and therefore the specific syntactical structures are preserved.

8.4 Idiomatic and Metaphor processing abilities in PD

The sixth aim was to investigate idiomatic and metaphor language processing in participants with PD. The findings revealed that the individuals with PD had significant difficulty processing idiomatic and metaphoric sentences. Moreover, individuals with PD had greater difficulty verbally providing the meaning of the target sentence compared to recognizing the meaning of the idiom and/or metaphor. This difficulty might partially reflect the word finding deficits of the PD participants in addition to reduced computational resources. Metaphor and idiomatic processing are cognitively demanding tasks for both comprehension and production of non-literal language.

The current findings are largely in line with what is reported in the literature specifically, that PD patients have difficulty processing metaphoric expressions and/or idiomatic language. In this case, the metaphor/idiom processing ability was correlated with executive function measures of verbal working memory (DBS) and set-shifting ability (TMT-B). The previous published research on metaphor processing in PD produced similar results. In their study Lewis, Lapointe, Murdoch, & Chenery (1998) claimed that the PD group had greater difficulty interpreting the metaphoric expressions and matching the metaphor with the sentence of the same meaning. Monetta

& Pell (2007) also found that PD participants had reduced accuracy in metaphor processing and this difficulty was correlated with deficits of verbal working memory. Working memory is important in the completion of cognitive and linguistic tasks because it temporarily maintains and manipulates information that is required for the individual to execute any given complex and demanding tasks (Baddeley, 2003, 2012). Clinical data propose that individuals with PD have difficulty in both tasks of maintaining and manipulating the information (Gilbert et al., 2005; Lewis et al., 2003). Berg et al. (2003) also found that individuals with PD performed significantly worse on the task of making references.

The findings from the study and results from earlier studies indicate that the individuals with PD have reduced cognitive resources and therefore are less efficient in making all the required indirect associations among the lexical items of the metaphoric expression. The set-shifting deficits may indicate the inability to complete all the required operations for accurate metaphor processing. The set-switching ability defined as the ability to shift between two or more cognitive tasks. The processing of metaphors/idioms consists of several mental tasks and thus the reduced set-shifting ability may contribute to the reduced performance. Even though it was not directly explored in this study, metaphor or non-literal language processing deficits could have a negative impact on everyday communication skills since are widely used metaphors in everyday communication.

Overall, the current findings indicate that the idiomatic and metaphor processing deficits are associated with executive dysfunction. The data concerning the neural circuitry for metaphor processing suggest that such an operation is linked to the integrity of pre-frontal and frontal brain areas. This provides a possible explanation for current results as the PD group performance is characterized by reduced performance on executive function tasks.

8.5 Synthesis of results

A reoccurring issue in the literature on PD is whether PD affects language processing directly or the language disorders are a byproduct of the concomitant cognitive deficits. The findings of this study support the correlational relationship between linguistic deficits and non-linguistic cognitive deficits. It was evident that executive dysfunction contributes to the observed language disorders. The PD group performed lower on the

neurocognitive measures of executive functions (TMT-B, phonemic fluency) compared to the neurotypical group. Executive dysfunction was correlated with the linguistic domains of word retrieval deficits and idiomatic-metaphor processing deficits. This is in line with the findings of previous research reports for lexical-semantic deficits as well as higher-level language processing tasks. Earlier published research has proposed that the cognitive deficits, particularly the executive dysfunction, contributes to language disorders in PD (Crescentini, Mondolo, Biasutti & Shallice, 2008). This includes verb production (Colman et al., 2009), sentence processing (Colman et al., 2011; Grossman et al., 2003) as well as metaphor processing (Monetta & Pell, 2007).

A possible explanation for this association between executive functions and language deficits can be based on the neuroanatomical underpinnings of language processing. It is now well established that neural system of language consists of a widespread neural network (Price, 2012) including several cortical (e.g., frontal lobe, temporal lobe) and subcortical areas (Ardila, Bernal, & Rosselli, 2016). Also, the linguistic functions share the same neural networks with non-linguistic cognitive skills (Geranmayeh, Wise, Mehta, & Leech, 2014; Mesulam, 1989). In neurodegenerative disease, the cortex is affected by diffuse damage that disrupts an extensive neural network responsible for language and cognitive functions (Radanovic & Mansur, 2017). To this end, the recent concept of neural multifunctionality supports this interplay between the linguistic functions and the non-linguistic cognitive functions (Cahana-Amitay & Albert, 2015; Cahana-Amitay & Albert, 2014). According to this model, language processing requires a dynamic interaction among several neural networks that support linguistic functions such as lexical, syntactic and discourse processing and non-linguistic cognitive functions (Cahana-Amitay & Albert, 2014). The interaction between the cognitive and language deficits in PD is illustrated below in figure 8.2.

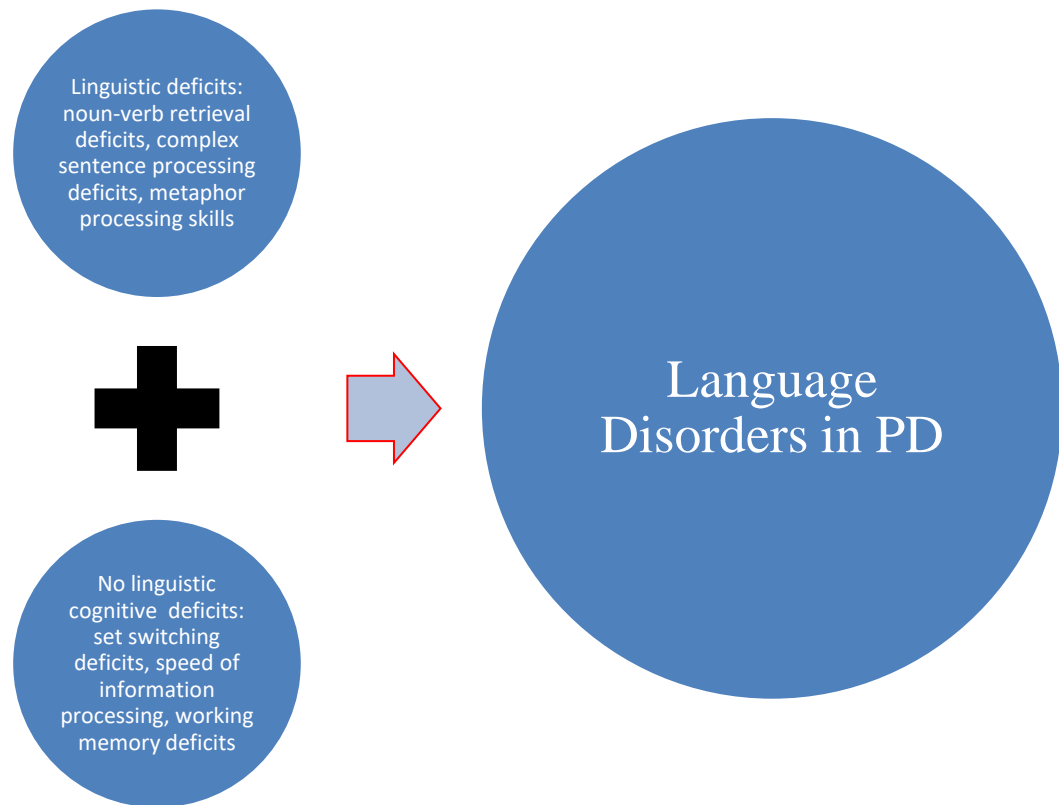


Figure 8.4: Interaction between cognitive and linguistic deficits in PD

8.6 Contribution of Executive Functions in naming

These findings suggest that executive dysfunction may coexist with language disorders in the PD group. The research data about how the frontal lobes contribute to word production is coming from other neuropathologies that also involve frontal lobe dysfunction. It is now well known that the neural networks that control language partially overlap with the ones that control executive functions including frontal, parietal, and several sub-cortical regions (Ye & Zhou, 2009). Current neuroimaging has indicated that frontal areas contribute to verb processing (Rofes & Miceli, 2014). Also, electrical stimulation of the prefrontal cortex has been found to reduce the latency for action naming (Cappa, Sandrini, Rossini, Sosta, & Miniussi, 2002) and the impairment in action naming was attributed to frontal lobe dysfunction (Cappa et al., 1998), while frontoparietal-subcortical neural networks contribute to action processing (Cotelli et al., 2006; Peterson et al., 2021).

Cardona et al. (2013) proposed that the frontotemporal neural networks that consist of connections between several cerebral areas and basal ganglia influence the processing

of action words. Action naming deficits in PD have been associated with frontal-striatum atrophy (Birba et al., 2017). Executive dysfunction in PD is associated with bilateral volume reduction in frontal regions (Duncan et al., 2016).

8.7 Summary

Overall, the PD group exhibited preserved auditory comprehension but a disproportional impairment in verb retrieval ability compared to noun retrieval ability. Noun and verb production deficits were characterized predominantly by semantic errors. Naming accuracy was affected by the visual complexity of the stimulus picture. The word retrieval difficulty was due to an underlying semantic deficit after the semantic level of processing and prior to phonological processing.

Based on the findings, the PD group did not perform significantly different to healthy controls on the semantic fluency task therefore it can be assumed that semantic memory is intact. This excludes the possibility that a generalized semantic deficit may exist. On the other hand, the performance on the phonological fluency task and on the TMT-B indicates that the cognitive profile of PD group is similar with the profile of frontal lobe dysfunction.

Taken together, the findings of this study are consistent with previous findings suggesting that non-demented individuals with PD have difficulty naming nouns and verbs. The results contribute to the existing limited research that concerns the semantic variables that may affect noun and verb naming ability in non-demented participants with PD. In neurodegenerative movement disorders the reduced action related semantic network may contribute to verb retrieval deficits (Vigliocco et al., 2011).

The two semantic factors that have been explored so far in previous studies concerning the verb retrieval ability in PD are the motor content (Bocanegra et al., 2017; Herrera et al., 2012) and manipulability (Cotelli et al., 2007). Instrumentality can be added to these two semantic factors as a variable that may influence verb retrieval ability.

The results revealed that Greek speaking individuals with PD have greater difficulty naming verbs than nouns on confrontation naming tasks of actions and objects. In addition, the finding of a verb and noun naming difficulty in Greek supports the concept that single word processing deficits are independent of any specific linguistic features of any given language. Considering the current published literature, it is obvious that the

same pattern of retrieval deficits is present in several different languages. Therefore, the current findings add to current body of evidence in this area.

To summarize, this research adds to the growing evidence regarding language-related processing deficits in PD. Importantly, this is the first body of research that has explored the cognitive-linguistic deficits in Greek-speaking PD participants and has documented action-related language deficits and metaphor processing deficits. All in all, the results revealed that PD group performed worse on neurocognitive tasks related to executive functions as well as on lexical tasks of noun and verb naming and idiomatic and metaphor processing skills.

Specifically, the PD group performed worse on noun and verb naming tasks compared to healthy participants. The present research explored the effects of instrumentality and name relation on noun and verb retrieval tasks in a group of Greek-speaking individuals with PD. However, the PD group performed better on naming instrumental verbs compared to non-instrumental verbs. Name relation did not affect the retrieval ability for either of the two grammatical categories that is name-related nouns and verbs (e.g., ‘brush’).

As it has been shown in a considerable body of studies, PD may be associated with cognitive difficulties on tasks related to executive functions. A number of studies have shown that individuals with PD could also have language difficulties on formal tests assessing lexical access in word production tasks, such as picture naming, semantic processing, and verbal fluency.

In this research, the PD group exhibited a lexical retrieval disorder that was more pronounced for verbs than nouns. Also, the verb retrieval ability was correlated with executive functions. Hence, it might be reasonably inferred that the language deficits in this PD group may not be exclusively linguistic in nature, but they may be viewed as a result of executive dysfunction. Several studies in the literature have also suggested this interpretation of the nature of the language disorders in PD. Nevertheless, additional studies are warranted.

There are a limited number of studies examining the language skills in Greek-speaking participants with PD. It can be concluded from the present study that the lexical processing skills in Greek-speaking individuals with PD may be affected.

Chapter 9: Clinical Implications

The current research has clinical implications for both assessment procedures as well as rehabilitation of language disorders in PD.

The findings emphasize the need for development of more specific language assessment protocols sensitive enough to detect the subtle linguistic deficits in the earliest stages of the disease. These protocols might offer insights into the language-related processes that are affected in PD. Clinical assessment tools for early identification of action verb retrieval deficits would provide the clinician with additional information regarding the naming abilities in individuals with PD.

The clinical data suggest that the cognitive decline as well as the language disorders is common findings even in the earliest stages of the disease. The current findings and the findings from other clinical studies emphasize the point of comprehensive clinical evaluation of languages skills in non-demented individuals with PD.

However, an issue that has not been explored yet in the PD related literature is the potential rehabilitation of the language disorders e.g., word-finding difficulties, sentence-processing deficits, etc. There are many research reports exploring the role of rehabilitation of cognitive deficits as well as the efficacy of speech therapy for motor speech disorders related to PD (e.g., hypokinetic dysarthria) but not for the language disorders. Specifically, there is published research evidence regarding the impact of cognitive rehabilitation in PD. A metanalysis proposed that cognitive rehabilitation has a positive impact on non-linguistic cognitive domains of executive functions, working memory and processing speed in PD (Leung et al., 2015). Based on this finding, an interesting hypothesis would be whether improving specific impaired non-linguistic cognitive functions such as executive functions, set switching abilities and working memory that are often affected during the course of PD, will improve the linguistic abilities of lexical retrieval or sentence processing. The current data derived from this study as well as from other published research justify such a hypothesis and recommend that it is worthy of testing.

To this end, a recent study conducted by Lee & Kim, (2020) investigated the impact of the cognitive rehabilitation of working memory on language production in a sample of individuals with AD. Four lexical tasks were administered for this purpose. The tasks included verbal fluency, a confrontation naming, a word definition, and a picture-

description task. The results revealed that the intervention on working memory deficits had a positive impact on language production skills. Also, a transfer and maintenance effect for all the tasks of language production was observed.

To the best of my knowledge, there is not yet a published study that has explored the impact of cognitive rehabilitation on language deficits such as those described in the present study. The association between cognitive and language disorders offers a new avenue for exploring the role of cognitive rehabilitation in language deficits in PD.

A further interesting hypothesis that is worth exploring is whether the performance in one or more language processing domains at a single time point during the early stages of the disease (mild motor symptoms, e.g., H&Y ≤ 1) or even in the preclinical period, could be utilized as a prognostic marker of the development of more severe language disorders in the later stages of the progression of the disease.

It is important to include a robust language assessment in addition to regular assessment of cognitive functions. In particular, the tasks of high-level language could possibly detect even the language disorders of mild severity.

The language deficits may be subtle enough especially in the early stages of the disease so that the individual with PD may not be experiencing communication difficulty in everyday life. Administering sensitive complex language assessment protocols may help in identifying mild language disorders and eventually help with the identification of patient PD subgroups that will present with more severe language impairment with progression of the disease.

This could contribute to clinical diagnosis of the disease. In everyday clinical practice, clinicians usually evaluate only the naming of nouns (e.g., administer the Boston Naming Test) and not verbs. Indeed, the clinical evaluation of both grammatical categories might offer more information about the lexical processing skills of the individuals with PD.

9.1 A proposed assessment for the cognitive-linguistic functions in PD

The aim of this section is to describe a protocol for clinical assessment of cognitive-linguistic abilities in individuals with PD. The lack of standardized clinical tools that can be used for the assessment of language abilities for individuals with PD is underscored.

With respect to evaluation of general language functions in individuals with PD, a tool that may be suitable for this purpose is the recently developed Mini Linguistic State Examination (MLSE:Patel, Peterson, Ingram, Storey, Cappa, Catricala, et al., 2020), a short comprehensive test that aims to evaluate the linguistic ability in individuals with primary progressive aphasia. The MLSE* is a multi-lingual test that was initially developed and validated for use in the English-speaking population. It has also been translated and adapted into Spanish (Matias-Guiu et al., 2021). It will soon be translated and adapted for Italian and Japanese as well as other languages. In addition to progressive aphasia, its clinical utility has been explored in assessing the linguistic abilities in individuals with different neurodegenerative motor disorders such as progressive supranuclear palsy and corticobasal syndrome (Peterson et al., 2021). In particular, the MLSE includes the lexical tasks of naming, repetition, complex sentence comprehension, word and non-word reading, written description, picture description, sentence repetition, articulation, descriptive speech, reading and writing. The translation and adaptation of this test in Greek, could provide the clinician with a brief and quick assessment tool suitable for everyday clinical practice. Proposed clinical tools for the cognitive and language abilities in clinical practice are presented in the following flowchart (see figure 9.1).

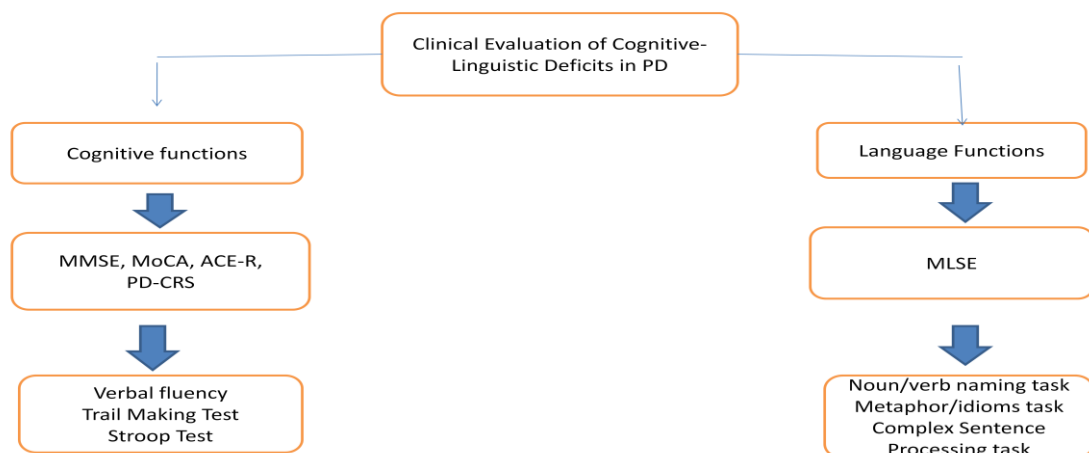


Figure 9.1: Flowchart of evaluation of cognitive and linguistic functions in PD

* An adaptation study for MLSE in Greek language is being currently conducted. The first results will be available during the end of this year.

Also, based on the findings of the present study as well as the findings from previous studies the evaluation of noun and verb retrieval ability is necessary during the language assessment. It is an easy-to-administer task and is not time consuming. This makes it appropriate for everyday clinical practice since the cognitive-linguistic deficits may be subtle in the early stages of the disease or even at the time of the initial clinical diagnosis of the disease. The clinical evidence suggests that the deficits in verb naming may serve as an early indicator of PD. Also, the inclusion of high-level language tasks such as metaphor processing could contribute to early diagnosis of PD.

Regarding the clinical assessment, aside from the MMSE, two additional neurocognitive screening tools that have been translated and adapted into Greek and could be administered by clinicians after training, are the Addenbrooke Cognitive Examination (Konstantinopoulou et al., 2011) and the Montreal Cognitive Assessment (Konstantopoulos, Vogazianos, & Doskas, 2016). It is important to mention that the MoCA provides cut-off scores for PDD for Greek-speaking individuals with PD. Also the Parkinson's Disease-Cognitive Rating Scale (Aretouli et al., 2021) has been adapted for the Greek population and could be a sensitive tool for screening cognitive functions. Given the lack of standardized language-related tools for Greek speaking individuals with neurogenic communication disorders, there is a great need for screening and diagnostic measures for individuals with PD. To this end, future studies should recruit larger samples to explore the clinical correlates of language deficits in PD.

9.1.1 PD and the ICF model

In the last two decades great interest has focused on how communication disorders impact on the everyday life of the person with the disorder. The goal of this section is to describe the cognitive-linguistic deficits associated with PD in the context of the World Health Organization's International Classification of Functioning, Disability and Health Framework (ICF) (World Health Organization, 2001). The framework consists of three basic subcategories:

- (a) Impairments in body functions and structures
- (b) Activity limitations
- (c) Participation restrictions

The ICF has also been used to describe the effect of communication disorders on the functional aspects of communication in adult population (Threats, 2006, 2007). The motor and non-motor symptoms that are related to PD impact all the components of the ICF (see table 9.1). Specifically, the severity of the body function symptoms as well as several barriers that may exist in the person's environment may increase the limitation of activities and the restriction of participation for individuals with PD (Leonardi et al., 2009). In addition, the presence of motor speech disorders and non-speech disorders may reduce the ability of the person to participate in communication related activities and increase the restrictions in participation in everyday activities (Rautara & Kant, 2018).

PD: Body functions and structures

PD is associated with specific neurodegeneration affecting cortical and subcortical brain regions. Cerebral atrophy progressively affects multiple brain regions, generating motor and non-motor symptoms. Structural and functional cerebral changes extending into the cortical-subcortical neural networks including frontal-striatum circuitry may affect several aspects of communication including speaking and understanding, reading and writing.

PD: Activities and Participation

Based on the findings of previous studies as well as the present study, PD has a negative impact on everyday communication skills as well as on quality of life of individuals with PD. Above all, people with PD may have trouble with word finding, difficulty understanding spoken words, phrases, or sentences and of course, difficulty understanding metaphors. These communication impairments will pose barriers to individuals with PD to participate in group discussions and potentially make them avoid a number of everyday communication activities that are language-demanding activities (e.g., going shopping, ordering a pizza, etc.).

A possible scenario is that an individual with PD might have difficulty finding the right word (anomia) in everyday communicative situations. This word finding difficulty could lead to a negative attitude and reduced self-confidence towards communication skills. As a result, the person will be forced to reduce their participation in everyday activities (i.e., participate in a conversation with one or multiple partners).

The task of participation in a common communicative situation such as the context of a discussion involves the interplay among several linguistic abilities (i.e., word finding, sentence formation, auditory comprehension) and non-linguistic cognitive functions (i.e., working memory, executive functions, attention). In addition, it is possible that in many everyday communicative situations, the person will have to process metaphors and idioms that are impaired in PD. These communication difficulties may be also encountered by individuals with mild language disorders especially in highly language-demanding tasks.

PD: Contextual factors

There are several contextual factors that may facilitate or impede the quality of communication skills of the individuals with PD. Negative personal factors may be the severity of motor symptoms as well as the presence of non-motor symptoms such as psychiatric disorders (e.g., depression) and cognitive dysfunction.

A contextual factor that may facilitate communication is the training of the medical team, the caregiver, and the communication partner on how to improve their communication skills with individuals with PD. There are structured training courses for persons with dementia (Smith et al., 2011; Ripich et al., 1999). These courses have been successful in improving the quality of communication interaction as well as the quality of life of both the trained individual and the individual with dementia. However, there is only one published study that has explored the effectiveness of such a training course in individuals with PD with positive results (Forsgren, Antonsson, & Saldert, 2017). The trained communication partners (e.g., medical personnel, family members, caregivers) will be better prepared to adjust their communication style and thus to improve the communication skills of the individuals with PD. The clinician might train the family in using communication strategies to improve communication in addition to providing therapy to the patient. Since communication takes two, it's of utmost importance the communication partner (e.g., the siblings, the caregiver, medical team) to be trained.

Table 9.1: ICF components for individuals with PD

ICF categories	Characteristics
<i>Body functions and structures</i>	Progressive neurodegeneration in cortical and subcortical brain regions. Cognitive-communicative disorder.
<i>Activities</i>	The individual is not able to communicate his/her ideas in everyday communicative situations .
<i>Participation</i>	The individual is not able to participate in discussions and other communicative situations.
<i>Environmental factors</i>	The physical and social environment in which the person lives. These factors may facilitate or restrict the individual's functioning.
<i>Personal factors</i>	Cognitive deficits, psychiatric disorders

9.2 Limitations

As in any other clinical study, the present study has some limitations that should be mentioned. The first limitation is the small sample of participants. However, a review of the relevant literature revealed that most of the published studies have recruited small number of participants (Cardona et al., 2013). However larger sample sizes will allow the better generalizability of these results.

The second potential limitation is the lack of a more detailed neuropsychological assessment. This might possibly offer more insights regarding the neurocognitive deficits in this sample. For instance, an additional measure of executive functions could have been a task assessing inhibition skills (e.g., stroop test) or additional assessment of noun and verb semantic processing ability beyond the single word level.

A cross-sectional research design was chosen for the purposes of this study. Therefore, the data represents each participant's performance at a certain point in time. However, a

longitudinal follow-up would offer more information about the rate of decline in linguistic abilities and on how the neurodegenerative process of PD affects language skills.

In addition, there was a lack of biomarker data for the PD group. The correlation between the linguistic measures and neuroimaging data (e.g., structural and/or functional brain changes), would offer valuable information about the language related neural substrates in PD.

9.3 Future directions

In the absence of clinical data regarding the linguistic skills in individuals with PD in Greece it is of outmost importance to further extend the current findings. A future longitudinal study of naming deficits would potentially provide additional data regarding the progression of the decline in lexical retrieval ability. Future efforts are warranted to refine and extend the experiments conducted in this study. Longitudinal studies are required to improve our knowledge about the role of language disorders in PD. Given the clinical heterogeneity of PD, the further exploration of the co-morbid spectrum of linguistic deficits accompanying PD is of high clinical significance.

Many clinical research studies have aimed to describe the neural underpinnings underlying the cognitive deficits in PD. Similarly, future endeavors should aim to explore whether the identification of a language related biomarker is possible in order to predict the progression of linguistic decline through longitudinal identification of structural and functional cerebral changes. Growing evidence shows that the linguistic changes might contribute to timely diagnosis of other neurodegenerative disorders (e.g., Mild Cognitive Impairment, Alzheimer's Dementia).

The clinical evidence from these studies will shed light on the underlying mechanisms of the language disorders in PD and therefore will contribute to the development of new avenues of treatment for the neurogenic communication disorders in this underserved clinical population.

References

- Aarsland, D., Batzu, L., Halliday, G. M., Geurtsen, G. J., Ballard, C., Chaudhuri, K. R., & Weintraub, D. (2021). Parkinson disease-associated cognitive impairment. *Nature Reviews Disease Primers*, 7(47), 1–21. <https://doi.org/10.1038/s41572-021-00280-3>
- Aarsland, D., Creese, B., Politis, M., Chaudhuri, K. R., ffytche, D. H., Weintraub, D., & Ballard, C. (2017). Cognitive decline in Parkinson disease. *Nature Reviews Neurology*, 13(4), 217–231. <https://doi.org/10.1038/nrneuro.2017.27>
- Alexander, G. E., DeLong, M. R., & Strick, P. L. (1986). Parallel organization of functionally linking basal ganglia and cortex. *Annual Review of Neuroscience*, 9, 357–381. <https://doi.org/10.1146/annurev.ne.09.030186.002041>
- Alonso-Recio, L., Martín-Plasencia, P., Ruiz, M., & Serrano, J. M. (2018). Differences in cognitive performance in nondemented Parkinson's disease: A latent profile analysis of cognitive subtypes. *Journal of Clinical and Experimental Neuropsychology*, 40(8), 777–789. <https://doi.org/10.1080/13803395.2018.1432570>
- Angwin, A. J., Chenery, H. J., Copland, D. A., Murdoch, B. E., & Silburn, P. A. (2007). The speed of lexical activation is altered in Parkinson's disease. *Journal of Clinical and Experimental Neuropsychology*, 29(1), 73–85.
- Ardila, A., Bernal, B., & Rosselli, M. (2016). How Localized are Language Brain Areas? A Review of Brodmann Areas Involvement in Oral Language. *Archives of Clinical Neuropsychology*, 31(1), 112–122. <https://doi.org/10.1093/arclin/acv081>
- Aretouli, E., Chondrogiorgi, M., Dede, O., Koutsonida, M., Lafi, C., Konstantinopoulou, E., ... Konitsiotis, S. (2021). The Parkinson's Disease-Cognitive Rating Scale: Greek Normative Data, Clinical Utility and Cultural Considerations. *Journal of Geriatric Psychiatry and Neurology*, 18. <https://doi.org/10.1177/08919887211049110>
- Armstrong, M. J., & Okun, M. S. (2020). Diagnosis and Treatment of Parkinson Disease: A Review. *JAMA - Journal of the American Medical Association*, 323(6), 548–560. <https://doi.org/10.1001/jama.2019.22360>
- Auclair-Ouellet, N., Lieberman, P., & Monchi, O. (2017). Contribution of language

- studies to the understanding of cognitive impairment and its progression over time in Parkinson's disease. *Neuroscience and Biobehavioral Reviews*, 80(August), 657–672. <https://doi.org/10.1016/j.neubiorev.2017.07.014>
- Auriacombe, S., Grossman, M., Carvell, S., Gollomp, S., Hurtig, M. B., & Stern, H. . (1993). Verbal Fluency Deficits in Parkinson's disease. *Neuropsychology*, 7(2), 182–192.
- Azuma, T., Bayles, K. A., Cruz, R. F., Tomoeda, C. K., Wood, J. A., & McGeagh, A. (1997). Comparing the difficulty of letter, semantic, and name fluency tasks for normal elderly and patients with Parkinson's disease. *Neuropsychology*, 488–497.
- Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, 36(3), 189–208. [https://doi.org/10.1016/S0021-9924\(03\)00019-4](https://doi.org/10.1016/S0021-9924(03)00019-4)
- Baddeley, A. (2012). Working Memory: Theories, Models, and Controversies. *Annual Review of Psychology*, 63(1), 1–29. <https://doi.org/10.1146/annurev-psych-120710-100422>
- Baiano, C., Barone, P., Trojano, L., & Santangelo, G. (2019). Prevalence and clinical aspects of mild cognitive impairment in Parkinson's disease: A meta-analysis. *Movement Disorders*, 35(1), 45–54. <https://doi.org/10.1002/mds.27902>
- Bak, T. H. (2013). The neuroscience of action semantics in neurodegenerative brain diseases. *Current Opinion in Neurology*, 26(6), 671–677. <https://doi.org/10.1097/WCO.0000000000000039>
- Baldo, J. V., Schwartz, S., Wilkins, D., & Dronkers, N. F. (2006). Role of frontal versus temporal cortex in verbal fluency as revealed by voxel-based lesion symptom mapping. *Journal of the International Neuropsychological Society*, 12(6), 896–900. <https://doi.org/10.1017/S1355617706061078>
- Balestrino, R., & Schapira, A. H. V. (2020). Parkinson disease. *European Journal of Neurology*, 27(1), 27–42. <https://doi.org/10.1111/ene.14108>
- Barone, P., Aarsland, D., Burn, D., & Emre, M. (2011). Cognitive Impairment in Nondemented Parkinson's Disease Cognitive Dysfunction in PD : Definitions and Features Pathophysiology of CI, 26(14), 2483–2495. <https://doi.org/10.1002/mds.23919>

- Bartels, A. L., & Leenders, K. L. (2009). Parkinson's disease: The syndrome, the pathogenesis and pathophysiology. *Cortex*, 45(8), 915–921.
<https://doi.org/10.1016/j.cortex.2008.11.010>
- Bastiaanse, R. (1991). Retrieval of instrumental verbs in aphasia: An explorative study. *Clinical Linguistics and Phonetics*, 5(4), 355–368.
<https://doi.org/10.3109/02699209108985902>
- Bastiaanse, R., & Leenders, K. L. (2009). Language and Parkinson's Disease. *Cortex*, 45(8), 912–914. <https://doi.org/10.1016/j.cortex.2009.03.011>
- Berg, E., Björnram, C., Hartelius, L., Laakso, K., & Johnels, B. (2003). High-level language difficulties in Parkinson's disease. *Clinical Linguistics & Phonetics*.
<https://doi.org/10.1080/0269920021000055540>
- Bertella, L., Albani, G., Greco, E., Priano, L., Mauro, A., Marchi, S., ... Semenza, C. (2002). Noun verb dissociation in Parkinson's disease. *Brain and Cognition*, 48(2–3), 277–280.
- Birba, A., García-Cordero, I., Kozono, G., Legaz, A., Ibáñez, A., Sedeño, L., & García, A. M. (2017). Losing ground: Frontostriatal atrophy disrupts language embodiment in Parkinson's and Huntington's disease. *Neuroscience and Biobehavioral Reviews*, 80(August), 673–687. <https://doi.org/10.1016/j.neubiorev.2017.07.011>
- Bocanegra, Y., García, A. M., Lopera, F., Pineda, D., Baena, A., Ospina, P., ... Cuetos, F. (2017). Brain & Language Unspeakable motion : Selective action-verb impairments in Parkinson ' s disease patients without mild cognitive impairment. *Brain and Language*, 168, 37–46. <https://doi.org/10.1016/j.bandl.2017.01.005>
- Bocanegra, Y., García, A. M., Pineda, D., Buriticá, O., Villegas, A., Lopera, F., ... Ibáñez, A. (2015). Syntax, action verbs, action semantics, and object semantics in Parkinson's disease: Dissociability, progression, and executive influences. *Cortex*, 69, 237–254. <https://doi.org/10.1016/j.cortex.2015.05.022>
- Bock, K., & Levelt, W. (2002). Language production. Grammatical encoding. In G. T. . Altmann (Ed.), *Psycholinguistics: Critical concepts in psychology* (London: Ro).
- Bohrn, I., Altmann, U., & Jacobs, A. (2012). Looking at the brains behind figurative language--a quantitative meta-analysis of neuroimaging studies on metaphor, idiom, and irony processing. *Neuropsychologia*, 50(12), 2669–2683.

<https://doi.org/10.1016/j.neuropsychologia.2012.07.021>

- Bohsali A, C. B. (2016). The basal ganglia and language: A tale of two loops. In *The basal ganglia* (pp. 217–242). Springer International Publishing.
- Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerod, M., & Nazir, T. a. (2008). Word processing in Parkinson’s disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia*, *46*(2), 743–756.
<https://doi.org/10.1016/j.neuropsychologia.2007.10.007>
- Bowdle, F. B., & Gentner, D. (2005). The career of metaphor. *Psychological Review*, *112*(1), 193–216.
- Braak, H., Del, K., Rüb, U., Vos, R. A. I. De, Jansen, E. N. H., & Braak, E. (2003). Staging of brain pathology related to sporadic Parkinson ’ s disease, *24*, 197–211.
- Breedin, S. D., Saffran, E. M., & Schwartz, M. F. (1998). Semantic factors in verb retrieval: An effect of complexity. *Brain and Language*, *63*(1), 1–31.
<https://doi.org/10.1006/brln.1997.1923>
- Cahana-amitay, D., & Albert, M. L. (2015). Neuroscience of Aphasia Recovery : the Concept of Neural Multifunctionality. <https://doi.org/10.1007/s11910-015-0568-7>
- Cahana-Amitay, D., & Albert, M. L. (2014). Brain and language: Evidence for neural multifunctionality. *Behavioural Neurology*, *2014*(1).
<https://doi.org/10.1155/2014/260381>
- Cappa, S. F., Sandrini, M., Rossini, P. M., Sosta, K., & Miniussi, C. (2002). The role of the left frontal lobe in action naming rTMS evidence. *Neurology*, *59*(5), 720–723.
<https://doi.org/10.1212/WNL.59.5.720>
- Cappa, S F, Padovani, A., Cotelli, M., Borroni, B., Manenti, R., Zanetti, M., & Are, A. (2007). Action and object naming in Parkinson ’ s disease without dementia, 632–637. <https://doi.org/10.1111/j.1468-1331.2007.01797.x>
- Cappa, Stefano F., Binetti, G., Pezzini, A., Padovani, A., Rozzini, L., & Trabucchi, M. (1998). Object and action naming in Alzheimer’s disease and frontotemporal dementia. *Neurology*, *50*(2). <https://doi.org/10.1212/wnl.50.2.351>
- Caramazza, A., & Miozzo, M. (1997). The relation between syntactic and phonological knowledge in lexical access: Evidence from the “tip-of-the-tongue” phenomenon.

- Cognition*, 64(3), 309–343. [https://doi.org/10.1016/S0010-0277\(97\)00031-0](https://doi.org/10.1016/S0010-0277(97)00031-0)
- Cardona, J. F., Gershanik, O., Gelormini-Lezama, C., Houck, A. L., Cardona, S., Kargieman, L., ... Ibáñez, A. (2013). Action-verb processing in Parkinson's disease: New pathways for motor-language coupling. *Brain Structure and Function*, 218(6), 1355–1373. <https://doi.org/10.1007/s00429-013-0510-1>
- Cloutman, L., Gottesman, R., Chaudhry, P., Davis, C., Kleinman, J. T., Pawlak, M., ... Hillis, A. E. (2009). Where (in the brain) do semantic errors come from? *Cortex*, 45(5), 641–649. <https://doi.org/10.1016/j.cortex.2008.05.013>
- Colman, K. S. F., Koerts, J., Stowe, L. A., Leenders, K. L., & Bastiaanse, R. (2011). Sentence Comprehension and Its Association with Executive Functions in Patients with Parkinson's Disease. *Parkinson's Disease*, 2011, 1–15. <https://doi.org/10.4061/2011/213983>
- Colman, K. S. F., Koerts, J., van Beilen, M., Leenders, K. L., Post, W. J., & Bastiaanse, R. (2009). The impact of executive functions on verb production in patients with Parkinson's disease. *Cortex*, 45(8), 930–942. <https://doi.org/10.1016/j.cortex.2008.12.010>
- Cools, R., Barker, R. A., Sahakian, B. J., & Robbins, T. W. (2001). Mechanisms of cognitive set flexibility in Parkinson's disease. *Brain: A Journal of Neurology*, 124(12), 2503–2512. <https://doi.org/10.1093/brain/124.12.2503>
- Copland, D. A., Brownsett, S., Iyer, K., & Angwin, A. J. (2021). Corticostriatal Regulation of Language Functions. *Neuropsychology Review*, (0123456789). <https://doi.org/10.1007/s11065-021-09481-9>
- Cotelli, M., Borroni, B., Manenti, R., Zanetti, M., Arévalo, a., Cappa, S. F., & Padovani, a. (2007). Action and object naming in Parkinson's disease without dementia. *European Journal of Neurology*, 14(6), 632–637. <https://doi.org/10.1111/j.1468-1331.2007.01797.x>
- Cotelli, M, Fatebenefratelli, D., & Calabria, M. (2006). Action and Object Naming in Frontotemporal Dementia , Progressive Supranuclear Palsy , and Corticobasal Degeneration. *Neuropsychology*, 20(5), 558–565. <https://doi.org/10.1037/0894-4105.20.5.558>
- Cotelli, M, Manenti, R., Brambilla, M., & Borroni, B. (2017). The role of the motor

- system in action naming in patients with neurodegenerative extrapyramidal syndromes. *CORTEX*. <https://doi.org/10.1016/j.cortex.2017.05.011>
- Cotelli, Maria, Manenti, R., & Brambilla, M. (2017). The role of the motor system in action naming in patients with neurodegenerative extrapyramidal syndromes. *CORTEX*, (June). <https://doi.org/10.1016/j.cortex.2017.05.011>
- Cousins, K. A. Q., & Grossman, M. (2017). Evidence of semantic processing impairments in behavioural variant frontotemporal dementia and Parkinson's disease. *Current Opinion in Neurology*, 30(6), 617–622. <https://doi.org/10.1097/WCO.0000000000000498>
- Crepaldi, D., Berlingeri, M., Paulesu, E., & Luzzatti, C. (2011). A place for nouns and a place for verbs? A critical review of neurocognitive data on grammatical-class effects. *Brain and Language*, 116(1), 33–49. <https://doi.org/10.1016/j.bandl.2010.09.005>
- Cristofori, I., Cohen-Zimmerman, S., & Grafman, J. (2019). *Executive functions. Handbook of Clinical Neurology* (1st ed., Vol. 163). Elsevier B.V. <https://doi.org/10.1016/B978-0-12-804281-6.00011-2>
- Crowley, S. J., Banan, G., Amin, M., Tanner, J. J., Hizel, L., Nguyen, P., ... Price, C. C. (2021). Statistically defined Parkinson's disease executive and memory cognitive phenotypes: Demographic, behavioral, and structural neuroimaging comparisons. *Journal of Parkinson's Disease*, 11(1), 283–297. <https://doi.org/10.3233/JPD-202166>
- Curtis, F. . . , Masellis, M., Davidson, R., Heather, T., & C, M. (2019). Cognitive profile of non-demented Parkinson's disease: Meta-analysis of domain and sex-specific deficits. *Parkinsonism & Related Disorders*, 60, 32–42. <https://doi.org/10.1016/j.parkreldis.2018.10.014>. Epub 2018 Oct 14
- da Silva, H. S., Machado, J., Cravo, A., Parente, M. A. de M. P., & Carthery-Goulart, M. T. (2014). Action/verb processing: Debates in neuroimaging and the contribution of studies in patients with parkinson's disease. *Dementia e Neuropsychologia*, 8(1), 3–13. <https://doi.org/10.1590/s1980-57642014dn81000002>
- Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differently

- distributed neural systems. *Proceedings of the National Academy of Sciences of the United States of America*, 90(11), 4957–4960.
<https://doi.org/10.1073/pnas.90.11.4957>
- Davie, C. A. (2008). A review of Parkinson's disease. *British Medical Bulletin*, 86(1), 109–127. <https://doi.org/10.1093/bmb/ldn013>
- Davis, A. A., & Racette, B. (2016). Parkinson disease and cognitive impairment: Five new things. *Neurology: Clinical Practice*, 6(5), 452–458.
<https://doi.org/10.1212/CPJ.0000000000000285>
- Dell, G. (1986). A Spreading-Activation Theory of Retrieval in Sentence Production, 93(3), 283–321.
- Dirnberger, G., & Jahanshahi, M. (2013). Executive dysfunction in Parkinson's disease : A review. *Journal of Neuropsychology*, 7(2), 193–224.
<https://doi.org/10.1111/jnp.12028>
- Dubois, B. (1997). Cognitive deficits in Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, (244), 2–8.
- Dubois, B., Burn, D., Goetz, C., Aarsland, D., Brown, R. G., Broe, G. A., ... Poewe, W. (2007). Diagnostic Procedures for Parkinson's Disease Dementia : Recommendations from the Movement Disorder Society Task Force, 22(16), 2314–2324. <https://doi.org/10.1002/mds.21844>
- Dujardin, K., Leentjens, A. F. G., Langlois, C., Moonen, A. J. H., Duits, A. A., Carette, A. S., & Duhamel, A. (2013). The spectrum of cognitive disorders in Parkinson's disease: A data-driven approach. *Movement Disorders*, 28(2), 183–189.
<https://doi.org/10.1002/mds.25311>
- Dujardin, K., Moonen, A. J. H., Behal, H., Defebvre, L., Duhamel, A., Duits, A. A., ... Leentjens, A. F. G. (2015). Cognitive disorders in Parkinson's disease: Confirmation of a spectrum of severity. *Parkinsonism and Related Disorders*, 21(11), 1299–1305. <https://doi.org/10.1016/j.parkreldis.2015.08.032>
- Duncan, G. W., Firbank, M. J., O'Brien, J. T., & Burn, D. J. (2013). Magnetic resonance imaging: A biomarker for cognitive impairment in Parkinson's disease? *Movement Disorders*, 28(4), 425–438. <https://doi.org/10.1002/mds.25352>

- El-Nazer, R., Adler, C. H., Beach, T. G., Belden, C. M., Artz, J., Shill, H. A., ... Benge, J. F. (2019). Regional Neuropathology Distribution and Verbal Fluency Impairments in Parkinson's Disease. *Parkinsonism & Related Disorders*, *65*, 73–78. <https://doi.org/10.1016/j.parkreldis.2019.05.014>
- Elgh, E., Domellöf, M., Linder, J., Edström, M., Stenlund, H., & Forsgren, L. (2009). Cognitive function in early Parkinson's disease: A population-based study. *European Journal of Neurology*, *16*(12), 1278–1284. <https://doi.org/10.1111/j.1468-1331.2009.02707.x>
- Emre, M., Aarsland, D., Brown, R., Burn, D. J., Duyckaerts, C., Mizuno, Y., ... Poewe, W. (2007). Clinical Diagnostic Criteria for Dementia Associated with Parkinson's Disease, *22*(12), 1689–1707. <https://doi.org/10.1002/mds.21507>
- Fengler, S., Liepelt-scarfone, I., Brockmann, K., Sch, E., Berg, D., & Kalbe, E. (2017). Cognitive Changes in Prodromal Parkinson's Disease : A Review ment Disorder Society. *Movement Disorders*, *32*(12), 1655–1666. <https://doi.org/10.1002/mds.27135>
- Fernandino, L., Conant, L. L., Binder, J. R., Blindauer, K., Hiner, B., Spangler, K., & Desai, R. H. (2013a). Parkinson's disease disrupts both automatic and controlled processing of action verbs. *Brain and Language*, *127*(1), 65–74. <https://doi.org/10.1016/j.bandl.2012.07.008>
- Fernandino, L., Conant, L. L., Binder, J. R., Blindauer, K., Hiner, B., Spangler, K., & Desai, R. H. (2013b). Where is the action ? Action sentence processing in Parkinson's disease. *Neuropsychologia*, *51*(8), 1510–1517. <https://doi.org/10.1016/j.neuropsychologia.2013.04.008>
- Filoteo, V., Reed, J., Litvan, I., & Harrington, D. (2014). Volumetric correlates of cognitive functioning in nondemented patients with Parkinson's disease. *Movement Disorders*, *29*(3).
- Flowers, K. A., Robertson, C., & Sheridan, M. R. (1995). Some characteristics of word fluency in Parkinson's disease. *Journal of Neurolinguistics*, *9*(1), 33–46.
- Forsgren, E., Antonsson, M., & Saldert, C. (2022). Training conversation partners of persons with communication disorders related to Parkinson's disease — a protocol and a pilot study, (February 2012), 82–90.

<https://doi.org/10.3109/14015439.2012.731081>

- Fountoulakis, K. N., Tsolaki, M., Chantzi, H., & Kazis, A. (2000). Mini Mental State Examination (MMSE): A validation study in Greece. *American Journal of Alzheimer's Disease and Other Dementias*, *15*(6), 342–345.
<https://doi.org/10.1177/153331750001500604>
- Geranmayeh, F., Wise, R. J. S., Mehta, A., & Leech, R. (2014). Overlapping networks engaged during spoken language production and its cognitive control. *Journal of Neuroscience*, *34*(26), 8728–8740. <https://doi.org/10.1523/JNEUROSCI.0428-14.2014>
- Gernsbacher, M. A., Keysar, B., Robertson, R. R. W., & Werner, N. K. (2001). The Role of Suppression and Enhancement in Understanding Metaphors☆. *Journal of Memory and Language*, *45*(3), 433–450. <https://doi.org/10.1006/jmla.2000.2782>
- Giannakou, M., Kosmides, M. E., Kiosseoglou, G., & Garyfallos, G. (2013). Adaptation of the Beck Depression inventory-II to Greek population. *Hellenic Journal of Psychology*, *10*, 120–146.
- Gleichgerrcht, E., Fridriksson, J., & Bonilha, L. (2015). Neuroanatomical foundations of naming impairments across different neurologic conditions. *Neurology*, *85*(3), 284–292. <https://doi.org/10.1212/WNL.0000000000001765>
- Glucksberg, S. (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences*, *7*(2), 92–96. [https://doi.org/10.1016/S1364-6613\(02\)00040-2](https://doi.org/10.1016/S1364-6613(02)00040-2)
- Goetz, C. G., Tilley, B. C., Shaftman, S. R., Stebbins, G. T., Fahn, S., Martinez-martin, P., ... Lapelle, N. (2008). Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale Presentation and Clinimetric Testing Results, *23*(15), 2129–2170.
<https://doi.org/10.1002/mds.22340>
- Gordon, J. K., & Dell, G. S. (2003). Learning to divide the labor: An account of deficits in light and heavy verb production. *Cognitive Science*, *27*(1), 1–40.
[https://doi.org/10.1016/S0364-0213\(02\)00111-8](https://doi.org/10.1016/S0364-0213(02)00111-8)
- Gordon, J. K., Young, M., Garcia, C., Gordon, J. K., Young, M., & Garcia, C. (2018). Why do older adults have difficulty with semantic fluency? Why do older adults

- have difficulty with semantic fluency? *Aging, Neuropsychology, and Cognition*, 25(6), 803–828. <https://doi.org/10.1080/13825585.2017.1374328>
- Grossman, M., Stern, M. B., Gollomp, S., Vernon, G., & Hurtig, H. I. (1994). Verb Learning in Parkinson's Disease, 8(3), 413–423.
- Grossman, M., Zurif, E., Lee, C., Prather, P., Kalmanson, J., Stern, M. B., & Hurtig, H. I. (2002). Information processing speed and sentence comprehension in Parkinson's disease. *Neuropsychology*, 16(2), 174–181. <https://doi.org/10.1037/0894-4105.16.2.174>
- Haber, S. N. (2016). Corticostriatal Circuitry. In D. W. Pfaff & D. . Volkow (Eds.), *Neuroscience in the 21st Century* (pp. 1–21). Springer Science+ Business Media New York. <https://doi.org/10.1007/978-1-4614-6434-1>
- Halliday, G., Hely, M. A., Reid, W. G. J., & Adena, M. A. (2008). The Sydney Multicenter Study of Parkinson's disease : the inevitability of dementia at 20 years The Sydney Multicenter Study of Parkinson's Disease : The Inevitability of Dementia at 20 years, (March 2016). <https://doi.org/10.1002/mds.21956>
- Hanley, J. R., Dewick, H. C., Davies, A. D., Playfer, J., & Turnbull, C. (1990). Verbal fluency in Parkinson's disease. *Neuropsychologia*, 28(7), 737–741. [https://doi.org/10.1016/0028-3932\(90\)90129-c](https://doi.org/10.1016/0028-3932(90)90129-c)
- Hatzigeorgiou, N., Gavrilidou, M., Piperidis, S., Carayannis, G., Papakostopoulou, A., Spiliotopoulou, A., & Al., E. (2000). Design and implementation of the online ILSP corpus. *Proceedings of the Second International Conference of Language Resources and Evaluation (LREC)*, Vol. 3, 1737–1740.
- Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic Representation of Action Words in Human Motor and Premotor Cortex. *Neuron*, 41(2), 301–307. [https://doi.org/10.1016/S0896-6273\(03\)00838-9](https://doi.org/10.1016/S0896-6273(03)00838-9)
- Henry, J. D., & Crawford, J. R. (2004). Verbal fluency deficits in Parkinson's disease: a meta-analysis. *Journal of International Neuropsychological Society*, 10(4), 608–622. <https://doi.org/10.1017/S1355617704104141>
- Herrera, E., Rodriguez-Ferreiro, J., & Cuetos, F. (2012). The effect of motion content in action naming by Parkinson's disease patients. In *cortex* (Vol. 8, pp. 4–8). <https://doi.org/10.1016/j.cortex.2010.12.007>

- Hietanen, M., & Teräväinen, H. (1986). Cognitive performance in early Parkinson's disease. *Acta Neurologica Scandinavica*, 73(2), 151–159.
<https://doi.org/10.1111/j.1600-0404.1986.tb03257.x>
- Higby, E., Cahana-amitay, D., Vogel-eyny, A., Iii, A. S., Martin, L., Obler, L. K., ... Iii, A. S. (2019). The Role of Executive Functions in Object- and Action-Naming among Older Adults The Role of Executive Functions in Object- and Action-Naming. *Experimental Aging Research*, 45(4), 306–330.
<https://doi.org/10.1080/0361073X.2019.1627492>
- Hoehn, M. M., & Yahr, M. D. (1967). Parkinsonism : onset , progression , and mortality. *Neurology*, 17(5), 427–442. <https://doi.org/10.1212/wnl.17.5.427>.
- Holton, D., Mackridge, P., & Philippaki-Warburton, I. (1997). *Greek: A comprehensive grammar of the modern language*. London: Routledge.
- Hoogland, J., van Wanrooij, L. L., Boel, J. A., Goldman, J. G., Stebbins, G. T., Dalrymple-Alford, J. C., ... Weintraub, D. (2018). Detecting Mild Cognitive Deficits in Parkinson's Disease: Comparison of Neuropsychological Tests. *Movement Disorders*, 33(11), 1750–1759. <https://doi.org/10.1002/mds.1110>
- Howard, D., & Gatehouse, C. (2006). Distinguishing semantic and lexical word retrieval deficits in people with aphasia. *Aphasiology*, 20(9–11), 921–950.
<https://doi.org/10.1080/02687030600782679>
- Hughes, A. J., Daniel, S. E., Kilford, L., & Lees, A. J. (1992). Accuracy of clinical diagnosis of idiopathic Parkinson's disease: A clinico-pathological study of 100 cases. *Journal of Neurology Neurosurgery and Psychiatry*, 55(3), 181–184.
<https://doi.org/10.1136/jnnp.55.3.181>
- Ibáñez, A., Cardona, J. F., Dos Santos, Y. V., Blenkmann, A., Aravena, P., Roca, M., ... Bekinschtein, T. (2013). Motor-language coupling: Direct evidence from early Parkinson's disease and intracranial cortical recordings. *Cortex*, 49(4), 968–984.
<https://doi.org/10.1016/j.cortex.2012.02.014>
- Johari, K., Walenski, M., Reifegerste, J., Ashrafi, F., Behroozmand, R., Daemi, M., & Ullman, M. T. (2019). A dissociation between syntactic and lexical processing in Parkinson's disease. *Journal of Neurolinguistics*, 51(July 2018), 221–235.
<https://doi.org/10.1016/j.jneuroling.2019.03.004>

- Jonkers, R., & Bastiaanse, R. (2007). Action naming in anomic aphasic speakers: Effects of instrumentality and name relation. *Brain and Language*, *102*(3), 262–272. <https://doi.org/10.1016/j.bandl.2007.01.002>
- Kambanaros, M. (2015). *The test of idioms and metaphors*.
- Kambanaros, Maria. (2003). *Verb and noun processing in late bilingual individuals with anomic aphasia. Unpublished PhD dissertation*. Flinders University, Adelaide, South Australia, Australia.
- Kambanaros, Maria. (2008). The trouble with nouns and verbs in Greek fluent aphasia. *Journal of Communication Disorders*, *41*, 1–19. <https://doi.org/10.1016/j.jcomdis.2007.02.001>
- Kambanaros, Maria, & Grohmann, K. K. (2015). Grammatical class effects across impaired child and adult populations. *Frontiers in Psychology*, *6*(NOV), 1–17. <https://doi.org/10.3389/fpsyg.2015.01670>
- Kambanaros, Maria, Messinis, L., & Anyfantis, E. (2012). Action and object word writing in a case of bilingual aphasia. *Behavioural Neurology*, *25*(3), 215–222. <https://doi.org/10.3233/BEN-2012-119006>
- Kambanaros, Maria, Messinis, L., Georgiou, V., & Papathanassopoulos, P. (2010). Action and object naming in schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, *32*(10), 1083–1094. <https://doi.org/10.1080/13803391003733578>
- Kambanaros, Maria, Messinis, L., Nasios, G., Nousia, A., & Papathanasopoulos, P. (2016). Verb–noun dissociations in relapsing-remitting multiple sclerosis: verb effects of semantic complexity and phonological relatedness. *Aphasiology*, *31*(1), 1–18. <https://doi.org/10.1080/02687038.2016.1154498>
- Kambanaros, Maria, Messinis, L., Nasios, G., Nousia, A., & Papathanasopoulos, P. (2017). Verb–noun dissociations in relapsing-remitting multiple sclerosis: verb effects of semantic complexity and phonological relatedness. *Aphasiology*, *31*(1), 49–66. <https://doi.org/10.1080/02687038.2016.1154498>
- Karpathiou, N., & Kambanaros, M. (2019). Comparing two cases of the non-fluent and semantic variants of primary progressive aphasia using neuropsychological, narrative and acoustic measures. In *Academy of Aphasia 57th Annual Meeting*,

- Macau, Macao, SAR China, 27 Oct - 29 Oct. rontiers in Human Neuroscience.
- Kehagia, A. A., Barker, R. A., & Robbins, T. W. (2010). Neuropsychological and clinical heterogeneity of cognitive impairment and dementia in patients with Parkinson's disease. *The Lancet Neurology*, 9(12), 1200–1213.
[https://doi.org/10.1016/S1474-4422\(10\)70212-X](https://doi.org/10.1016/S1474-4422(10)70212-X)
- Kehagia, A., Barker, R. A., & Robbins, T. W. (2010). Neuropsychological and clinical heterogeneity of cognitive impairment and dementia in patients with Parkinson's disease. *The Lancet Neurology*, 9(12), 1200–1213. [https://doi.org/10.1016/S1474-4422\(10\)70212-X](https://doi.org/10.1016/S1474-4422(10)70212-X)
- Kehagia, A., Barker, R., & Robbins, T. W. (2012). Cognitive Impairment in Parkinson's Disease : The Dual Syndrome Hypothesis Cognitive Impairment in Parkinson's Disease : The Dual Syndrome Hypothesis, (October).
<https://doi.org/10.1159/000341998>
- Kemmerer, D. (2014). Word classes in the brain: implications of linguistic typology for cognitive neuroscience. *Cortex*, 58, 27–51.
<https://doi.org/10.1016/j.cortex.2014.05.004>
- Kemmerer, D., & Tranel, D. (2000). Verb Retrieval in Brain-Damaged Subjects : 1 . Analysis of Stimulus , Lexical , and Conceptual Factors. *Brain and Cognition*, 392, 347–392. <https://doi.org/10.1006/brln.2000.2311>
- Key-delyria, S. E., & Altmann, L. J. P. (2016). Executive Function and Ambiguous Sentence Comprehension. *American Journal of Speech-Language Pathology*, 25(May), 252–267. <https://doi.org/10.1044/2015>
- Klepac, N., Trkulja, V., Relja, M., & Babic, T. (2008). Is quality of life in non-demented Parkinson's disease patients related to cognitive performance ? A clinic-based cross-sectional study, 128–133. <https://doi.org/10.1111/j.1468-1331.2007.02011.x>
- Koenig, J. P., Maurer, G., Bienvenue, B., & Conklin, K. (2008). What with? The anatomy of a (proto)-role. *Journal of Semantics*, 25(2), 175–220.
<https://doi.org/10.1093/jos/ffm013>
- Konstantinopoulou, E., Kosmidis, M. H., Ioannidis, P., Kiosseoglou, G., Karacostas, D., & Taskos, N. (2011). Adaptation of Addenbrooke's Cognitive Examination-

- Revised for the Greek population. *European Journal of Neurology*, 18(3), 442–447. <https://doi.org/10.1111/j.1468-1331.2010.03173.x>
- Konstantopoulos, K., Vogazianos, P., & Doskas, T. (2016). Normative Data of the Montreal Cognitive Assessment in the Greek Population and Parkinsonian Dementia. *Archives of Clinical Neuropsychology*, 31(3), 246–253. <https://doi.org/10.1093/arclin/acw002>
- Kosmidis, M. H., Vlahou, C. H., Panagiotaki, P., & Kiosseoglou, G. (2004). The verbal fluency task in the Greek population: Normative data, and clustering and switching strategies. *Journal of the International Neuropsychological Society*, 10(2), 164–172. <https://doi.org/10.1017/S1355617704102014>
- Kotz, S. A., Schwartze, M., & Schmidt-Kassow, M. (2009). Non-motor basal ganglia functions: A review and proposal for a model of sensory predictability in auditory language perception. *Cortex*, 45(8), 982–990. <https://doi.org/10.1016/j.cortex.2009.02.010>
- Kourtidou, P., Kasselimis, D., Potagas, C., & Zalonis, I. (2015). Effects of Mental Flexibility and Motor Dysfunction on Cognitive Performance in Patients With Parkinson ' s Disease. *Archives of Neuroscience*, 2(3), 4–7. <https://doi.org/10.5812/archneurosci.21087>
- Koziol, L. F., & Budding, D. E. (2009). *Subcortical structures and cognition: Implications for neuropsychological assessment. Subcortical Structures and Cognition: Implications for Neuropsychological Assessment*. <https://doi.org/10.1007/978-0-387-84868-6>
- Kudlicka, A., Clare, L., & Hindle, J. V. (2011). Executive Functions in Parkinson ' s Disease : Systematic Review and Meta-Analysis Definitions of EF and Related Concepts Challenges in Researching EF. *Movement Disorders*, 26(13), 2305–2315. <https://doi.org/10.1002/mds.23868>
- Lee, C., Grossman, M., Morris, J., Stern, M. B., & Hurtig, H. I. (2003). Attentional resource and processing speed limitations during sentence processing in Parkinson ' s disease. *Journal of Clinical Neuropsychology*, 85, 347–356. [https://doi.org/10.1016/S0093-934X\(03\)00063-4](https://doi.org/10.1016/S0093-934X(03)00063-4)
- Lee, M. ., & Kim, S. . (2020). Effects of working memory intervention on language production by individuals with dementia. *Neuropsychological Rehabilitation*,

- 17(0), 1–25. <https://doi.org/10.1080/09602011.2020.1789479>
- Leh, S. E., Ptito, A., Chakravarty, M. M., & Strafella, A. P. (2007). Fronto-striatal connections in the human brain: A probabilistic diffusion tractography study. *Neuroscience Letters*, *419*(2), 113–118.
<https://doi.org/10.1016/j.neulet.2007.04.049>
- Leonardi, M., Meucci, P., Ajovalasit, D., Albanesi, F., Cerniauskaite, M., Invernizzi, V., ... Raggi, A. (2009). ICF in neurology: Functioning and disability in patients with migraine, myasthenia gravis and Parkinson's disease. *Disability and Rehabilitation*, *31*(SUPPL. 1), 88–99. <https://doi.org/10.3109/09638280903317732>
- Leung, I. H. K., Walton, C. C., Hallock, H., Lewis, S. J. G., Valenzuela, M., & Lampit, A. (2015). Cognitive training in Parkinson disease: A systematic review and meta-analysis. *Neurology*, *85*(21), 1843–1851.
<https://doi.org/10.1212/WNL.0000000000002145>
- Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*(1), 1–75.
<https://doi.org/10.1017/S0140525X99001776>
- Lewis, Fiona, M., Lapointe, L. L., Murdoch, B. E., & Chenery, H. J. (1998). Language impairment in Parkinson's disease. *Aphasiology*, *12*(3), 193–206.
<https://doi.org/10.1080/02687039808249446>
- Lewis, J. W. (2006). Cortical networks related to human use of tools. *Neuroscientist*, *12*(3), 211–231. <https://doi.org/10.1177/1073858406288327>
- Lewis, S. J. G., Dove, A., Robbins, T. W., Barker, R. A., & Owen, A. M. (2003). Cognitive Impairments in Early Parkinson's Disease Are Accompanied by Reductions in Activity in Frontostriatal Neural Circuitry. *The Journal of Neuroscience*, *23*(15), 6351–6356. <https://doi.org/10.1523/JNEUROSCI.23-15-06351.2003>
- Litvan, I., ShaoSchmand, B. A., Weintraub, D., Goldman, J. G., Tro, A. I., Petersen, R. C., ... Kulisevsky, J. (2012). Diagnostic Criteria for Mild Cognitive Impairment in Parkinson's Disease : Movement Disorder Society Task Force Guidelines

- Methodology The MDS Task Force first reviewed literature on the Current Methods of Defining MCI Different criteria for def. *Movement Disorders*, 27(3), 349–356. <https://doi.org/10.1002/mds.24893>
- Logishetty, K., & Chaudhuri, K. R. (2009). Parkinson ' s disease. In K. R. Chaudhuri & O. G. William (Eds.), *Handbook of Movement Disorders* (pp. 1–31). Springer Science+Business Media.
- Lombardi, L., & Potter, M. C. (1990). The Regeneration of Syntax in Short-Term Memory. *Journal of Memory and Language*, 733, 1–49.
- Macdonald, S. (2017). Introducing the model of cognitive-communication competence : A model to guide evidence-based communication interventions after brain injury. *Brain Injury*, 31(13–14), 1760–1780. <https://doi.org/10.1080/02699052.2017.1379613>
- Mak, E., Su, L., Williams, G. B., Firbank, M. J., Lawson, R. A., Yarnall, A. J., ... O'Brien, J. T. (2015). Baseline and longitudinal grey matter changes in newly diagnosed Parkinson's disease: ICICLE-PD study. *Brain*, 138(10), 2974–2986. <https://doi.org/10.1093/brain/awv211>
- Malyutina, S., Dragoy, O., Ivanova, M., Laurinavichyute, A., Petrushevsky, A., Meindl, T., ... Gutyrchik, E. (2016). Fishing is not wrestling: Neural underpinnings of the verb instrumentality effect. *Journal of Neurolinguistics*, 40, 37–54. <https://doi.org/10.1016/j.jneuroling.2016.03.002>
- Malyutina, S., Iskra, E., & Sevan, D. (2014). Aphasiology The effects of instrumentality and name relation on action naming in Russian speakers with aphasia, 28(May), 37–41. <https://doi.org/10.1080/02687038.2014.910589>
- Matison, R., Mayeux, R., Rosen, J., & Fahn, S. (1982). “Tip-of-the-tongue” phenomenon in Parkinson disease. *Neurology*, 32(5), 567–570. Retrieved from [10.1212/wnl.32.5.567](https://doi.org/10.1212/wnl.32.5.567)
- Matzig, S., Druks, J., Masterson, J., & Vigliocco, G. (2009). Noun and verb differences in picture naming : Past studies and new evidence. *Cortex*, 45, 738–758. <https://doi.org/10.1016/j.cortex.2008.10.003>
- Melloni, M., Sedeño, L., Hesse, E., García-Cordero, I., Mikulan, E., Plastino, A., ... Ibáñez, A. (2015). Cortical dynamics and subcortical signatures of motor-language

- coupling in Parkinson's disease. *Scientific Reports*, 5, 1–11.
<https://doi.org/10.1038/srep11899>
- Mesulam, M. M. (n.d.). Large-scale neurocognitive networks and distributed processing for attention language and memory.
- Meteyard, L., Cuadrado, S. R., Bahrami, B., & Vigliocco, G. (2012). Coming of age: A review of embodiment and the neuroscience of semantics. *Cortex*, 48(7), 788–804.
<https://doi.org/10.1016/j.cortex.2010.11.002>
- Middleton, F. A., & Strick, P. L. (2000). Basal ganglia and cerebellar loops: Motor and cognitive circuits. *Brain Research Reviews*, 31(2–3), 236–250.
[https://doi.org/10.1016/S0165-0173\(99\)00040-5](https://doi.org/10.1016/S0165-0173(99)00040-5)
- Miller, N. (2017). Communication changes in Parkinson's disease. *Practical Neurology*, 17(4), 266–274. <https://doi.org/10.1136/practneurol-2017-001635>
- Mitchum, C. C., Ritgert, B. ., Sandson, J., & Berndt, R. S. (1990). The use of response analysis in confrontation naming The use of response analysis in confrontation naming. *Aphasiology*, 4(3), 37–41.
- Monetta, L., & Pell, M. D. (2007). Effects of verbal working memory deficits on metaphor comprehension in patients with Parkinson's disease, 101, 80–89.
<https://doi.org/10.1016/j.bandl.2006.06.007>
- Moreau, C., & Pinto, S. (2019). Misconceptions about speech impairment in Parkinson's disease. *Movement Disorders*, 34(10), 1471–1475.
<https://doi.org/10.1002/mds.27791>
- Murdoch, B. E. (2001). Subcortical brain mechanisms in speech and language. *Folia Phoniatica et Logopaedica*, 53(5), 233–251. <https://doi.org/10.1159/000052679>
- Muslimović, D., Post, B., Speelman, J. D., & Schmand, B. (2005). Cognitive profile of patients with newly diagnosed Parkinson disease. *Neurology*, 65(8), 1239–1245.
<https://doi.org/10.1212/01.wnl.0000180516.69442.95>
- Natsopoulos, D., Grouios, G., Bostantzopoulou, S., Mentenopoulos, G., Katsarou, Z., & Logothetis, J. (1993). Algorithmic and heuristic strategies in comprehension of complement clauses by patients with Parkinson's disease. *Neuropsychologia*, 31(9), 951–964. [https://doi.org/10.1016/0028-3932\(93\)90150-X](https://doi.org/10.1016/0028-3932(93)90150-X)

- Natsopoulos, D., Katsarou, Z., Bostantzopoulou, S., Grouios, G., Mentenopoulos, G., & Logothetis, J. (1991). Strategies in Comprehension of Relative Clauses by Parkinsonian Patients. *Cortex*, *27*(2), 255–268. [https://doi.org/10.1016/S0010-9452\(13\)80130-X](https://doi.org/10.1016/S0010-9452(13)80130-X)
- Obeso, I., Casabona, E., Bringas, M. ., Lazaro, A., & Jahanshahia, M. (2012). Semantic and phonemic verbal fluency in Parkinson ’ s disease : Influence of clinical and demographic variables. *Behavioral Neurology*, *25*, 111–118. <https://doi.org/10.3233/BEN-2011-0354>
- Owen, A. M. (2004). Cognitive Dysfunction in Parkinson’s Disease: The Role of Frontostriatal Circuitry. *The Neuroscientist*, *10*(6), 525–537. <https://doi.org/10.1177/1073858404266776>
- Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*, *76*, 1–25. <https://doi.org/10.1037/h0025327>
- Papagno, C., Mattavelli, G., Cattaneo, Z., Romito, L., & Albanese, A. (2013). Ambiguous idiom processing in Parkinson’s disease patients. *Cognitive Neuropsychology*, *30*(7–8), 495–506. <https://doi.org/10.1080/02643294.2013.876397>
- Parkinson, J. (2002). An essay on the shaking palsy. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *14*(2), 223–236. <https://doi.org/10.1176/jnp.14.2.223>
- Péran, P., Cardebat, D., Cherubini, A., Piras, F., Luccichenti, G., Peppe, A., ... Sabatini, U. (2009). Object naming and action-verb generation in Parkinson’s disease: A fMRI study. *Cortex*, *45*(8), 960–971. <https://doi.org/10.1016/j.cortex.2009.02.019>
- Peran, P., Rascol, O., Démonet, J., Celsis, P., Nespoulous, J., & Dubois, B. (2003). Deficit of Verb Generation in Nondemented Patients with Parkinson ’ s Disease. *Movement Disorders*, *18*(2), 150–156. <https://doi.org/10.1002/mds.10306>
- Pereira, J. B., Junque, C., Ramirez-ruiz, B., & Bartre, D. (2009). Structural brain correlates of verbal fluency in Parkinson ’ s disease. *Neuroreport*, 741–744. <https://doi.org/10.1097/WNR.0b013e328329370b>
- Pereira, J. B., Svenningsson, P., Weintraub, D., Brønnick, K., Lebedev, A., Westman, E., & Aarsland, D. (2014). Initial cognitive decline is associated with cortical

- thinning in early Parkinson disease. *Neurology*, 82(22), 2017–2025.
<https://doi.org/10.1212/WNL.0000000000000483>
- Peterson, K. A., Jones, P. S., Patel, N., Tsvetanov, K. A., Ingram, R., Cappa, S. F., ... Rowe, J. B. (2021). Language Disorder in Progressive Supranuclear Palsy and Corticobasal Syndrome: Neural Correlates and Detection by the MLSE Screening Tool. *Frontiers in Aging Neuroscience*, 13(July).
<https://doi.org/10.3389/fnagi.2021.675739>
- Pfeiffer, H. C. V., Løkkegaard, A., Zoetmulder, M., Friberg, L., & Werdelin, L. (2014). Cognitive impairment in early-stage non-demented Parkinson's disease patients. *Acta Neurologica Scandinavica*, 129(5), 307–318.
<https://doi.org/10.1111/ane.12189>
- Pigott, K., Rick, J., Xie, S. X., Hurtig, H., Chen-plotkin, A., Duda, J. E., ... Trojanowski, J. Q. (2015). Longitudinal study of normal cognition in Parkinson disease. *Neurology*, 85(13), 1276–1282.
- Postuma, R. B., Berg, D., Stern, M., Poewe, W., Olanow, C. W., Oertel, W., ... Deuschl, G. (2015). MDS clinical diagnostic criteria for Parkinson's disease. *Movement Disorders*, 30(12), 1591–1601. <https://doi.org/10.1002/mds.26424>
- Potter, M. C., & Lombardi, L. (1990). Recall in the Short-Term of Sentences Regeneration. *Journal of Memory and Language*, 45(4), 633–654.
[https://doi.org/10.1016/0749-596X\(90\)90042-X](https://doi.org/10.1016/0749-596X(90)90042-X)
- Price, C. J. (2012). A review and synthesis of the first 20 years of PET and fMRI studies of heard speech, spoken language and reading. *NeuroImage*, 62(2), 816–847.
<https://doi.org/10.1016/j.neuroimage.2012.04.062>
- Pulvermüller, F., Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience*, 21(3), 793–797. <https://doi.org/10.1111/j.1460-9568.2005.03900.x>
- Radanovic, M., & Mansur, L. L. (2017). Aphasia in vascular lesions of the basal ganglia: A comprehensive review. *Brain and Language*, 173, 20–32.
<https://doi.org/10.1016/j.bandl.2017.05.003>
- Rapp, A. M., Grodd, W., Kircher, T., Rapp, A. M., Grodd, W., Erb, M., ... Erb, M. (2004). Neural correlates of metaphor processing. *Cognitive Brain Research*,

- daniel. <https://doi.org/10.1016/j.cogbrainres.2004.03.017>
- Rapp, A. M., & Wild, B. (2011). Nonliteral language in Alzheimer dementia: a review. *Journal of the International Neuropsychological Society : JINS*, 17(2), 207–218. <https://doi.org/10.1017/S1355617710001682>
- Rautara, M. S., & Kant, A. R. (2018). Utilization of ICF Framework for Assessment of Speech and Non-Speech Characteristics of Individuals with Parkinson ' s disease, 8(November), 217–225.
- Reid, W. G. J., Hely, M. A., Morris, J. G. L., Loy, C., & Halliday, G. M. (2011). Dementia in Parkinson ' s disease : a 20-year neuropsychological study (Sydney Multicentre Study). *Journal of Neurology Neurosurgery and Psychiatry*. <https://doi.org/10.1136/jnnp.2010.232678>
- Ripich, D. N., Ma, E. Z., Ma, F., & Ma, E. J. D. (n.d.). Training Alzheimer ' s Disease Caregivers for Successful Communication, (June 2012), 37–41.
- Robinson, G., Shallice, T., Bozzali, M., & Cipolotti, L. (2012). The differing roles of the frontal cortex in fluency tests. *Brain*, 135(7), 2202–2214. <https://doi.org/10.1093/brain/aws142>
- Rodríguez-Ferreiro, J., Cuetos, F., Herrera, E., Menéndez, M., & Ribacoba, R. (2010). Cognitive impairment in Parkinson's disease without dementia. *Movement Disorders*, 25(13), 2136–2141. <https://doi.org/10.1002/mds.23239>
- Rodríguez-Ferreiro, J., Menéndez, M., Ribacoba, R., & Cuetos, F. (2009). Action naming is impaired in Parkinson disease patients. *Neuropsychologia*, 47(14), 3271–3274. <https://doi.org/10.1016/j.neuropsychologia.2009.07.007>
- Rodriguez-Oroz, M. C., Jahanshahi, M., Krack, P., Litvan, I., Macias, R., Bezard, E., & Obeso, J. A. (2009). Initial clinical manifestations of Parkinson's disease: features and pathophysiological mechanisms. *The Lancet Neurology*, 8(12), 1128–1139. [https://doi.org/10.1016/S1474-4422\(09\)70293-5](https://doi.org/10.1016/S1474-4422(09)70293-5)
- Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1997). The psychological construct of word fluency. *Brain and Language*, 57(3), 394–405. <https://doi.org/10.1006/brln.1997.1755>
- Salmazo-Silva, H., Parente, M. A. de M. P., Rocha, M. S., Baradel, R. R., Cravo, A. M.,

- Sato, J. R., ... Carthey-Goulart, M. T. (2017). Lexical-retrieval and semantic memory in Parkinson's disease: The question of noun and verb dissociation. *Brain and Language*, 165, 10–20. <https://doi.org/10.1016/j.bandl.2016.10.006>
- Sánchez-Cubillo, I., Periañez, J. A., Adrover-Roig, D., Rodríguez-Sánchez, J. M., Ríos-Lago, M., Tirapu, J., & Barceló, F. (2009). Construct validity of the Trail Making Test : Role of task-switching , working memory , inhibition / interference control , and visuomotor abilities. *Journal of the International Neuropsychological Society*, 15, 438–450. <https://doi.org/10.1017/S1355617709090626>
- Sawamoto, N., Piccini, P., Hotton, G., Pavese, N., Thielemans, K., & Brooks, D. J. (2008). Cognitive deficits and striato-frontal dopamine release in Parkinson's disease. *Brain*, 131(5), 1294–1302. <https://doi.org/10.1093/brain/awn054>
- Schalling, E., Johansson, K., & Hartelius, L. (2018). Speech and Communication Changes Reported by People with Parkinson's Disease. *Folia Phoniatria et Logopaedica*, 69(3), 131–141. <https://doi.org/10.1159/000479927>
- Schapira, A. H. V, Chaudhuri, K. R., & Jenner, P. (2017). Non-motor features of Parkinson disease. *Nature Publishing Group*, 18(7), 435–450. <https://doi.org/10.1038/nrn.2017.62>
- Seger, C. A. (2006). The basal ganglia in human learning. *Neuroscientist*, 12(4), 285–290. <https://doi.org/10.1177/1073858405285632>
- Shao, Z., Janse, E., Visser, K., & Meyer, S. A. (2014). What do verbal fluency tasks measure ? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology*, 5(July), 1–10. <https://doi.org/10.3389/fpsyg.2014.00772>
- Shao, Zeshu, Roelofs, A., & Meyer, A. S. (2012). Sources of individual differences in the speed of naming objects and actions : The contribution of executive control Sources of individual differences in the speed of naming objects and actions : The contribution of e. *The Quarterly Journal of Experimental Psychology*, 65(10), 1927–1944.
- Silveri, C. M., Ciccarelli, N., Baldonero, E., Piano, C., Zinno, M., Soleti, F., ... Daniele, A. (2012). Neuropsychologia Effects of stimulation of the subthalamic nucleus on naming and reading nouns and verbs in Parkinson ' s disease. *Neuropsychologia*, 50(8), 1980–1989. <https://doi.org/10.1016/j.neuropsychologia.2012.04.023>

- Sloot, P., & Jonkers, R. (2011). Benoemen van acties door Alzheimerpatiënten Effect van instrumentaliteit en naamsverwantschap, *17*(2), 3–18.
- Small, J. a, Kemper, S., & Lyons, K. (2000). Sentence repetition and processing resources in Alzheimer's disease. *Brain and Language*, *75*, 232–258.
<https://doi.org/10.1006/brln.2000.2355>
- Smith, E. R., Broughton, M., Baker, R., Pachana, N. A., Angwin, A. J., Humphreys, M. S., ... Chenery, H. J. (2011). Memory and communication support in dementia : research-based strategies for caregivers, 256–263.
<https://doi.org/10.1017/S1041610210001845>
- Smith, K. M., & Caplan, D. N. (2018). Communication impairment in Parkinson's disease: Impact of motor and cognitive symptoms on speech and language. *Brain and Language*, *185*(December 2017), 38–46.
<https://doi.org/10.1016/j.bandl.2018.08.002>
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning & Memory*, *6*, 174–215.
- Spezzano, C. ., & Radanovic, M. (2010). Naming abilities Differentiation between objects and verbs in aphasia. *Dementia and Neuropsychology*, *4*(4), 287–292.
 Retrieved from <http://www.redalyc.org/articulo.oa?id=339529019006>
- Suhr, J. A., & Jones, R. D. (1998). Letter and semantic fluency in Alzheimer's, Huntington's, and Parkinson's dementias. *Archives of Clinical Neuropsychology*, *13*(5), 447–454.
- Tekin, S., & Cummings, J. L. (2002). Frontal-subcortical neuronal circuits and clinical neuropsychiatry: An update. *Journal of Psychosomatic Research*, *53*(2), 647–654.
[https://doi.org/10.1016/S0022-3999\(02\)00428-2](https://doi.org/10.1016/S0022-3999(02)00428-2)
- Terzi, A., Papapetropoulos, S., & Kouvelas, E. D. (2005). Past tense formation and comprehension of passive sentences in Parkinson's disease: Evidence from Greek. *Brain and Language*, *94*(3), 297–303. <https://doi.org/10.1016/j.bandl.2005.01.005>
- Tessa, C., Lucetti, C., Giannelli, M., Diciotti, S., Poletti, M., Danti, S., ... Toschi, N. (2014). Progression of brain atrophy in the early stages of Parkinson's disease: A longitudinal tensor-based morphometry study in de novo patients without cognitive

- impairment. *Human Brain Mapping*, 35(8), 3932–3944.
<https://doi.org/10.1002/hbm.22449>
- Threats, T. T. (2006). Towards an international framework for communication disorders: Use of the ICF. *Journal of Communication Disorders*, 39(4), 251–265.
<https://doi.org/10.1016/j.jcomdis.2006.02.002>
- Threats, T. T. (2007). Access for persons with neurogenic communication disorders : Influences of Personal and Environmental Factors of the ICF. *Aphasiology*, 21(1), 67–80. <https://doi.org/10.1080/02687030600798303>
- Tranel, D., Kemmerer, D., Adolphs, R., Damasio, H., & Damasio, A. R. (2003). Neural correlates of conceptual knowledge for actions. *Cognitive Neuropsychology*, 20(3–6), 409–432. <https://doi.org/10.1080/02643290244000248>
- Tremblay, L., Worbe, Y., Thobois, S., Sgambato-Faure, V., & Féger, J. (2015). Selective dysfunction of basal ganglia subterritories: From movement to behavioral disorders. *Movement Disorders*, 30(9), 1155–1170.
<https://doi.org/10.1002/mds.26199>
- Vigliocco, G., Vinson, D. P., Druks, J., Barber, H., & Cappa, S. F. (2011). Nouns and verbs in the brain: A review of behavioural, electrophysiological, neuropsychological and imaging studies. *Neuroscience and Biobehavioral Reviews*, 35(3), 407–426. <https://doi.org/10.1016/j.neubiorev.2010.04.007>
- Wang, X., & Cheng, Z. (2020). Cross-Sectional Studies: Strengths, Weaknesses, and Recommendations. *Chest*, 158(1), S65–S71.
<https://doi.org/10.1016/j.chest.2020.03.012>
- Weintraub, D., Tröster, A. I., Marras, C., & Stebbins, G. (2018). Initial cognitive changes in Parkinson’s disease. *Movement Disorders*, 33(4), 511–519.
<https://doi.org/10.1002/mds.27330>
- Williams-Gray, C., Foltynie, T., Brayne, C. E. G., Robbins, T. W., & Barker, R. A. (2007). Evolution of cognitive dysfunction in an incident Parkinson ’ s disease cohort. *Brain*, 13, 1787–1798. <https://doi.org/10.1093/brain/awm111>
- Wilshire, EC., & Coslett, B. H. (2000). Disorders of words retrieval in aphasia: theories and potential applications. In B. Nadeau, E.s., Rothi, G.J.L & Crosson (Ed.), *Aphasia and language:from theory to practice* (pp. 82–107). Guilford press.

- Wilson, H., Niccolini, F., Pellicano, C., & Politis, M. (2019). Cortical thinning across Parkinson's disease stages and clinical correlates. *Journal of the Neurological Sciences*, 398(July 2018), 31–38. <https://doi.org/10.1016/j.jns.2019.01.020>
- Wolff, L., & Bengtson, J. (2019). Everyday language difficulties in parkinson's disease: Caregiver description and relationship with cognition, activities of daily living, and motor disability. *American Journal of Speech-Language Pathology*, 28(1), 165–173. https://doi.org/10.1044/2018_AJSLP-18-0091
- World Health Organization. (2001). *ICF: International classification of functioning, disability and health*. Geneva: World Health Organization.
- Yang, J., Shu, H., Bi, Y., Liu, Y., & Wang, X. (2011). Dissociation and association of the embodied representation of tool-use verbs and hand verbs: An fMRI study. *Brain and Language*, 119(3), 167–174. <https://doi.org/10.1016/j.bandl.2011.06.001>
- Yarnall, A. J., Breen, D. P., Duncan, G. W., Khoo, T. K., Coleman, S. Y., Firbank, M. J., ... Burn, D. J. (2014). Characterizing mild cognitive impairment in incident Parkinson disease : The ICICLE-PD Study. *Neurology*, 82(4), 308–316. <https://doi.org/10.1212/WNL.0000000000000066>
- Ye, Z., & Zhou, X. (2009). Executive control in language processing. *Neuroscience and Biobehavioral Reviews*, 33(8), 1168–1177. <https://doi.org/10.1016/j.neubiorev.2009.03.003>
- Yuan, P., & Naftali, R. (2014). Prefrontal cortex and executive functions in healthy adults: A meta-analysis of structural neuroimaging studies. *Neuroscience & Biobehavioral Reviews*, 42, 180–192.
- Zalonis, I., Kararizou, E., Triantafyllou, N. I., Kapaki, E., Papageorgiou, S., Sgouropoulos, P., & Vassilopoulos, D. (2007). A normative study of the trail making test A and B in Greek adults. *Clinical Neuropsychologist*, 22(5), 842–850. <https://doi.org/10.1080/13854040701629301>
- Zhang, Y., Wang, K., Yue, C., Mo, N., Wu, D., Wen, X., & Qiu, J. (2018). The motor features of action verbs: fMRI evidence using picture naming. *Brain and Language*, 179(2), 22–32. <https://doi.org/10.1016/j.bandl.2018.02.002>

Appendix A

Target nouns and verbs on the Greek Object and Action Test (GOAT).

Instrumental nouns (name relation) (n=16)

ποτιστήρι (watering can)

αναπτήρας (lighter)

τρίφτης (grater)

λίμα (nail file)

ξυράφι (razor)

ζυγαριά (scales)

χτένα (comb)

σκούπα (broom)

Κόλλα (glue)

κλειδί (key)

σίδηρο (iron)

τρυπάνι (drill)

σφυρίχτρα (whistle)

σφουγγαρίστρα (mop)

ξύστρα (sharpener)

κόσκινο (sieve)

Instrumental nouns (non-name relation) (n = 14)

μολύβι (pencil)

σφυρί (hammer)

μικρόφωνο (microphone)

στυλό (pen)

κουτάλι (spoon)

ψαλίδι (scissors)

σφουγγάρι (sponge)

τσουγκράνα (rake)

καλάμι (fishing rod)

κατσαρόλα (saucepan)

μυστρί (trowel)

πινέλο (paint brush)

δίσκος (tray)

βελόνα (needle)

Non-instrumental nouns (n = 12)

σχοινί (rope)

σκάλα (ladder)

τηλεόραση (television)

φάκελος (envelope)

γραβάτα (tie)

κουδούνι (bell)

γάντι (glove)

μπαλόνι (balloon)

ρολόι (watch)

κρεβάτι (bed)

καναπέζ (couch)

εφημερίδα (newspaper)

Verbs

Instrumental verbs (no name relation) (n = 14)

ζωγραφίζει (drawing)

καρφώνει (hammering)

τραγουδάει (singing)

γράφει (writing)
ανακατεύει (stirring)
κόβει (cutting)
πλένει (washing)
μαζεύει (raking)
ψαρεύει (fishing)
μαγειρεύει (cooking)
χτίζει (building)
βάφει (painting)
ράβει (sewing)
σερβίρει (serving)

Instrumental verbs (name related) (n = 16)

ποτίζει (watering)
ανάβει (lighting)
τρίβει (grating)
λιμάρει (filing)
ξυρίζει (shaving)
ζυγίζει (weighing)
χτενίζει (combing)
σκουπίζει (sweeping)
κολλάει (glueing)
κλειδώνει (locking)
σιδερώνει (ironing)
τρυπάει (drilling)
σφυρίζει (whistling)
σφουγγαρίζει (mopping)

ξύνει (sharpening)

κοσκινίζει (sieving)

Non-instrumental verbs (n = 12)

τραβάει (pulling)

ανεβαίνει (climbing)

βλέπει (watching)

στέλνει (sending)

δένει (tying)

χτυπάει (hitting)

φοράει (wearing)

φουσκώνει (blowing)

κουρδίζει (winding)

κοιμάται (sleeping)

κάθεται (sitting)

διαβάζει (reading)

Appendix B

Greek Sentence Repetition Test

Recorded sentence to be repeated by the participant	Target Structure
Η μητέρα έβαλε τις μπλούζες των κοριτσιών στο μπαλκόνι.	SVO
Ο ζωγράφος θέλει να μην πιάνουν οι φίλοι του τους πίνακές του.	negation
Τον καφέ τον ήπια βιαστικά ο παππούς χθες στο καφενείο.	CLLD/CLD
Ο χορευτής πήρε την ομπρέλα του και περπάτησε στη δυνατή βροχή.	coordination
Ο παπάς έβλεπε πολλή ώρα τους τουρίστες που διάβαζαν τις πινακίδες.	compl. clause
Έκοψε το αγγούρι αφού καθάρισε καλά με νερό τις ντομάτες.	adverbial
Η δασκάλα δεν είναι σίγουρη ποιο βιβλίο διάβασε η μαθήτριά της.	wh-question
Ο αστυνόμος είδε την κοπέλα που του είχε πουλήσει ένα παγωτό.	relative clause
Ο τουρίστας ξέχασε τον οδηγό των διακοπών στο σπίτι.	SVO
Ο προπονητής δεν ελπίζει να κερδίσει η ομάδα του σήμερα.	negation
Ο γεωργός τον φύτεψε τον κήπο του θείου μου με μικρές κερασιές.	CLLD/CLD
Η μαγειρίσσα σήκωσε το βιβλίο της και το έβαλε	coordination

στο συρτάρι.	n
Η γιαγιά θυμόταν ότι σε αυτά τα μέρη πετούσαν περίεργα πουλιά.	compl. clause
Ο δάσκαλος πήγε κινηματογράφο ενώ προτιμούσε να παίζει κιθάρα.	adverbial
Μόνο ο αστυνόμος γνώριζε τι έκλεψαν από το σαλόνι οι ληστές.	wh-question
Οι εφημερίδες γράφουν πολλά για τον ληστή που έπιασε η αστυνομία.	relative clause
Ο manάβης πούλησε τις ώριμες φράουλες στην αγορά πολύ φθηνά.	SVO
Ο αθλητής ελπίζει ο αντίπαλός του να μην κερδίσει τον αγώνα.	negation
Την ταινία την είδε χτες ο δάσκαλος με τους μαθητές στο σινεμά.	CLLD/CLD
Ο μαθητής αγόρασε μαρκαδόρους και ο φίλος του πήρε μολύβια.	coordination
Οι μαθήτρες έκλαιγαν που ο διευθυντής πούλησε τον πίνακά τους.	compl. clause
Ο γείτονας αγόρασε το αυτοκίνητο πριν πουλήσει το μικρό σπίτι.	adverbial
Ο προπονητής ρώτησε τον αθλητή τι ύψος είχε ο πατέρας του.	wh-question
Η καθαρίστρια κλώτσησε τη νοσοκόμα που βγήκε από το γραφείο.	relative clause
Οι οδηγοί άφησαν τους επιβάτες των λεωφορείων	SVO

στην επόμενη στάση.	
Ο μάγειρας δεν πρότεινε να ψηθεί το ψάρι στο φούρνο.	negation
Το κορίτσι την έντυσε την κούκλα του με όμορφα φορέματα.	CLLD/CLD
Η μαμά μαγείρευε μακαρόνια και η γιαγιά έφτιαξε μια πίτα.	coordination
Οι νοσοκόμες είπαν ότι η πτήση του γιατρού έχει καθυστέρηση.	compl. clause
Όταν το σχολείο έκλεισε το καλοκαίρι, τα παιδιά έτρεχαν στους δρόμους.	adverbial
Η πεταλούδα ρώτησε τη μέλισσα τι θα φορούσε στη γιορτή.	wh-question
Ο τζίτζικας διάβαζε ένα βιβλίο που έγραψε ο βασιλιάς της ζούγκλας.	relative clause

Appendix C

Test of Idioms and Metaphors (TIM)

	ΚΑΤΑΝΟΗΣΗ ΜΕΤΑΦΟΡΩΝ	ΑΠΑΝΤΗΣΗ
	Κατανόηση Τι σημαίνει...;	
1	Του 'στριψε η βίδα	A) Τρελάθηκε B) Αγχώθηκε Γ) Μπερδεύτηκε
2	Μου έγινε βραχνάς	A) Με πιέζει ψυχολογικά B) Με θέλει Γ) Με στενεύει
3	Του μίλησε έξω από τα δόντια	A) Του μίλησε αυστηρά B) Του μίλησε ξεκάθαρα Γ) Δεν τολμά να μιλήσει
4	Έχω ένα κεφάλι καζάνι	A) Έχω πολλές σκέψεις B) Είμαι άρρωστος/ή Γ) Έχω πονοκέφαλο
5	Μαζεύτηκε εκεί κάθε καρδιάς καρύδι	A) Όλοι τρελοί εδώ B) Μαζεύτηκαν κάθε είδους άνθρωποι Γ) Όλοι μαζί ενωμένοι

6	Τον κόλλησα στον τοίχο	A) Πέφτει ξύλο B) Λέει ψέματα Γ) Τον αποστόμωσα
7	Πνίγεται σε μια κουταλιά νερό	A) Δεν μπορεί να ανταπεξέλθει σε δυσκολίες B) Φοβάται Γ) Αγχώνεται
8	Μασάει τα λόγια του	A) Με αποφεύγει B) Δεν σταματά να μιλά Γ) Δεν μιλάει ξεκάθαρα
9	Δεν ξέρω τι μαγειρεύουν	A) Δεν ξέρω τι ύπουλο σχεδιάζουν B) Λένε ψέματα Γ) Με κοροϊδεύουν
10	Αυτός δε μου γεμίζει το μάτι	A) Αυτός είναι νευρικός B) Αυτός είναι ύπουλος Γ) Αυτός δεν μου εμπνέει εμπιστοσύνη
11	Είναι σαν τη μέρα με τη νύχτα	A) Είναι εντελώς διαφορετικοί B) Δεν ταιριάζουν Γ) Ταιριάζουν

12	Δεν τα σηκώνει κάτι τέτοια	A) Δεν τα ανέχεται αυτά B) Είναι σκληρός Γ) Δεν σηκώνει συζήτηση
13	Κάνω μαύρα μάτια να δω κάποιον	A) Έχω πολύ καιρό να δω κάποιον B) Έχω χαθεί από όλους Γ) Δεν ξέρω που είμαι
14	Χάνω τα λόγια μου	A) Μιλώ σε κάποιον χωρίς να βρίσκω ανταπόκριση B) Δεν ξέρω τι λέω Γ) Σταματώ να μιλώ τώρα
15	Χάνω τ' αυγά και τα πασχάλια	A) Χάνω τα πάντα/χρεοκοπώ B) Θέλω περισσότερα από όσα έχω Γ) Δεν έχω τίποτα
16	Σαν το σκύλο με τη γάτα	A) Για ανθρώπους που μαλώνουν συνεχώς B) Για ανθρώπους που είναι φίλοι Γ) Για ανθρώπους που δεν ξέρουν τι τους γίνεται
17	Σαν βρεγμένη γάτα	A) Νιώθω αμηχανία B) Ταπεινωμένος Γ) Νοιώθω άσχημα

18	Ρίχνω μαύρη πέτρα πίσω μου	A) Έφυγα από το σπίτι B) Δεν θέλω να τους ξαναδώ Γ) Φεύγω αποφασισμένος να μην επιστρέψω ποτέ
19	Ρίχνω άδεια, να πιάσω γεμάτα	A) Προσπαθώ με έμμεσο τρόπο να μάθω κάτι B) Αδιαφορώ Γ) Λέω κακίες
20	Ρίχνω το γάντι σε κάποιον	A) Προκαλώ, απαιτώ ξεκαθάρισμα B) Ταπεινώνομαι Γ) Συκοφαντώ
21	Ρίχνομαι στη φωτιά για κάποιον	A) Κάνω τον ανήξερο B) Θυσιάζομαι για κάποιον Γ) Αφοσιώνομαι
22	Χάλασα τον κόσμο	A) Αναστάτωσα τα πάντα B) Κατάστρεψα τα πάντα Γ) Έχασα τα πάντα
23	Για τα μάτια του κόσμου	A) Κάνω κάτι για την πλάκα B) Κάνω κάτι γιατί το θέλω Γ) Κάνω κάτι για να το δουν οι άλλοι

24	Ζει στον κόσμο του	A) Δεν έχει επαφή με την πραγματικότητα B) Έχει επαφή με όλο τον κόσμο Γ) Δεν επικοινωνεί
25	Δε χάλασε κι ο κόσμος	A) Όλα πήγαν στραβά B) Δεν είναι κάτι σοβαρό Γ) Όλα θα πάνε καλά
26	Έρθε ο κόσμος τα πάνω κάτω	A) Δεν έγιναν αλλαγές B) Έγιναν λίγες αλλαγές Γ) Έγιναν μεγάλες αλλαγές
27	Μας πότισε όλους φαρμάκι	A) Μας χαροποίησε όλους B) Μας πίκρανε όλους Γ) Μας δυσκολεύει όλους
28	Κοιμάται με τις κότρες	A) Κοιμάται πολύ νωρίς B) Κοιμάται πολύ αργά C) Δεν κοιμάται
29	Του τα βγάζεις με το τσιγκέλι ή είναι σφίγγα	A) Του παίρνει κανείς λόγια με δυσκολία B) Δεν του παίρνεις λόγια C) Του παίρνει κανείς με ευκολία λόγια

30	Τραβάει τα μαλλιά του	A) Δεν είναι καλά B) Έπαθε κρίση C) Βρίσκεται σε απόγνωση

	ΠΑΡΑΓΩΓΗ ΜΕΤΑΦΟΡΩΝ	ΑΠΑΝΤΗΣΗ
	Τι εννοούμε όταν λέμε.....	
1	Έχει καβαλήσει το καλάμι	
2	Δεν σηκώνει μύγα στο σπαθί του	
3	Βγάζει από τη μύγα ξίγκι	
4	Του γεννούν και τα κοκόρια	
5	Το ένα του βρομά και το άλλο του μυρίζει	
6	Ο σκοπός αγιάζει τα μέσα	
7	Χτίζω πύργο στην άμμο	
8	Ρίχνω λάδι στη φωτιά	
9	Τράβηξε το χαλί κάτω από τα πόδια μου	
10	Μπήκε στη μύτη μας	

11	Βράζει στο ζουμί του	
12	Μια χαρά και δύο τρομάρες	
13	Κάνει το άσπρο μαύρο	
14	Έχει λερωμένη τη φωλιά του	
15	Τον έχει μη στάξει και μη βρέξει	

Appendix D

Examples of the picture stimuli



Example 1: hammer - σφυρί



Example 2: μυστρί -trowel



Example3: ποτιστήρι-watering can



Example 4: καρφώνει-hammering



Example 5: μαγειρεύει- cooking