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Language Production in Parkinson’s Disease:

An investigation into the characteristics and underlying cognitive and linguistic mechanisms

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Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Rebecca Wagstaff

Date: 29th March 2021

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Abstract

Research into language alteration in Parkinson's Disease (PD) remains relatively limited. Findings to date indicate that both a specific verb processing deficit and altered sentence construction can present as part of the symptom profile. However, questions regarding the underlying nature of the verb processing deficit observed remain and, as far as can be established, no studies have explicitly explored whether the altered verb processing evidenced may be underpinning the observed alteration in measures of sentence construction. This thesis reports on the findings from four component studies, each addressing an identified gap within the current literature relating to verb and sentence processing.

Of interest within the first two experimental research questions was the influence of the verb's semantic and grammatical characteristics on retrieval within both a single word and sentence context, and on various measures of sentence construction. In the main, the pattern of performance did not vary between individuals with PD and controls. Average pause length was found to be longer in sentences produced by individuals with PD, however was not influenced by the verb's characteristics.

The third experimental question was concerned with investigating sentence production within tasks which varied in their nature and linguistic demands. Again, performance was largely comparable between groups, with the exception of average pause length. Whilst pauses were found to be longer in PD, this was not influenced by the demands of the task.

Finally, exploratory correlational analyses were conducted to explore the relationship between the linguistic measures taken, and measures of various

cognitive abilities. Patterns of association varied between the groups, indicating a complex relationship between language and cognitive measures.

The majority of findings went against the predictions made. Collectively, findings indicate that, when verb processing is unimpaired in PD and cognitive functioning of a comparative level to controls, sentence construction is largely unimpaired.

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Glossary of Linguistic Terms

Intransitive verb *(one argument verb)*

Does not take an object – e.g., ‘I stumble’

Transitive optional verb *(one or two argument verb)*

Can take an object but not obligatory – e.g., ‘The girl is counting (her money)’

Transitive verb *(two argument verb)*

Must take an object – e.g., ‘I ignored the doorbell’

Ditransitive optional verb *(one, two or three argument verb)*

Can take up to two objects but not obligatory – e.g., ‘the woman is teaching (the children maths)’.

These two objects can be expressed through two alternating structures: the double object construction (DOC; e.g., ‘The man is buying the girl a car’) and a prepositional construction (PREP; e.g., ‘The man is buying a car for the girl’). Whilst these constructions are generally agreed to be synonymous, there is some disagreement as to the syntactic status of the second object in conditions within which the verb can take only one or other construction (see Gerwin, 2014, for useful disucssion). Thus, for the purpose of this study only verbs whose associated objects could be realised both through the DOC and PREP structures were considered to be ditransitive (i.e., verbs within which the order of the direct and indirect object can be alternated).

1 Introduction and Background

1.1 Introduction to the Thesis

The overarching aim of this project was to extend current knowledge regarding how language processing is affected by Parkinson's Disease (PD) and particularly *why* any such changes may be presenting. Whilst conducted as a whole, the study explored multiple research questions, each of which occupy their own chapter within this thesis.

The theoretical background following this introduction opens with an overview of PD, its symptomology and underlying pathology. The remainder of the chapter is divided into two overarching sections: the first concerned with cognitive alteration in PD and the second providing a detailed review of current literature regarding language processing in PD. This is followed by a summary of the overall literature and the identified gaps within it, from which the questions addressed within the current thesis arose. The chapter closes with presentation of the four research and component sub-research questions.

Chapter 2 provides detail of the general methodology adopted across the whole project. Provided here is detail of the overall research design and procedures, the recruitment protocol employed, and the analytical measures applied.

Chapter 3 details the nature of the general linguistic and cognitive profile established for PD and control participants, which formed the backbone of the project. The chapter moves through an overview of the methods employed, the results from the tasks employed and closes with a discussion of the overall findings.

Chapters 4-7 cover the experimental research questions and associated studies. All chapters follow the same outline, starting with the methods adopted and proceeding to a detailed overview of the results obtained followed by a summary of findings. Each chapter is concluded with a general discussion, relating to all findings obtained in relation to the research question under consideration.

Chapter 8 brings together findings from across the entire study in a general discussion. Included within this chapter is a detailed reflection of the study's limitations. The chapter closes with final conclusions, and directions for future research.

1.2 Theoretical Background

Parkinson's Disease (PD) is one of the most common neurodegenerative conditions (second only to Alzheimer's Disease; Hirtz et al., 2007), currently affecting approximately 145,000 people in the UK (Parkinson's UK, n.d.). Alongside the characteristic motor features of bradykinesia, rigidity, tremor and postural instability, PD is accompanied by a myriad of secondary motor and non-motor features (including sleep disturbance and autonomic dysfunction; Chaudhuri, Healy, & Schapira, 2006), with symptomatic profiles and rates of disease progression varying considerably between individuals (Jankovic, 2008; Kalia & Lang, 2015).

The two pathological hallmarks of PD are the selective loss of dopaminergic neurons – primarily within the Substantia Nigra pars compacta (SNc) and Ventral Tegmental Area (VTA; Brichta & Greengard, 2014) – and the presence of Lewy Body pathology (Lewy bodies and Lewy neurites) within both surviving neurons of the SNc and within a number of other neuronal groups in the central and peripheral (autonomic and enteric) nervous system (Alexander, 2004; Xu & Pu, 2016). Dopamine modulates activity within the circuits and pathways of the basal ganglia;

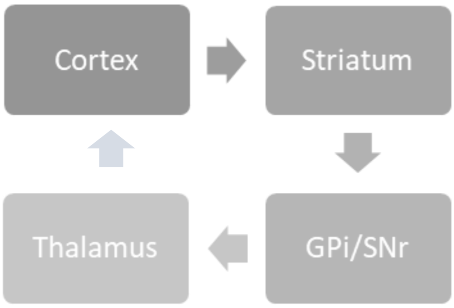
the components of which will be expanded upon in the following section. A number of other neurotransmitter systems are also implicated in PD, namely the cholinergic, noradrenergic, serotonergic, glutamatergic and GABAergic systems (Alexander, 2004; Barone, 2010; Buddhala et al., 2015). Changes within these systems have been linked to a number of the non-motor symptoms of PD, either directly or as a result of altered neurotransmitter balance (Alexander, 2004; Barone, 2010; Buddhala et al., 2015).

The Basal Ganglia

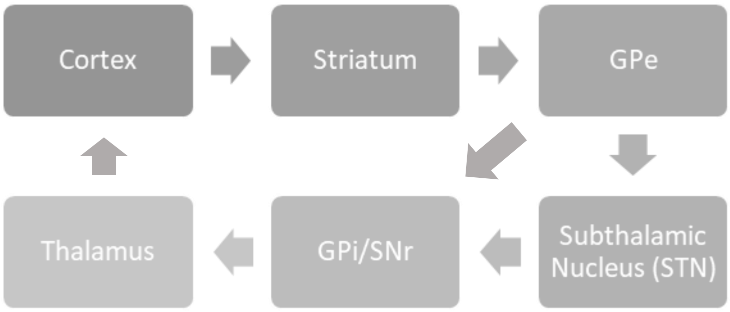
The basal ganglia are a collection of four, grey matter subcortical structures made up of the Striatum (putamen, caudate nucleus and the nucleus accumbens), the Globus Pallidus (Internal [GPi] and External [GPe]), the Substantia Nigra (pars reticulata [SNr] and pars compacta [SNc]) and the Subthalamic Nucleus (STN).Information enters the basal ganglia primarily from the cortex, with additional projections from the brainstem and thalamus (DeLong & Wichmann, 2010). The main input structure is the striatum, however projections are also received directly by the STN (DeLong & Wichmann, 2010; Lanciego, Luquin, & Obeso, 2012). The GPi and SNr act as output nuclei, projecting to the brainstem and thalamus, the latter stricture of which in turn then projects back to widespread areas of the frontal cortex (DeLong & Wichmann, 2010; Lanciego, Luquin, & Obeso, 2012). The ventral pallidum also acts an output nuclei within the limbic loop. The GPe acts solely as an intrinsic nuclei, whilst the STN also acts as intrinsic nuclei within the indirect pathway (Lanciego et al., 2012).

Three pathways between the input and output nuclei have been proposed: one facilitatory (the direct pathway) and two inhibitory (the indirect and hyperdirect pathway). As illustrated in Figure 1, due to the pathway taken, activation along the hyperdirect pathway is outlined to be faster than that of the indirect pathway (Nambu, Tokuno, & Takada, 2002).

Direct Pathway (DeLong & Wichmann, 2010)



Indirect Pathway (Alexander, 2004; DeLong & Wichmann, 2010)



Hyperdirect Pathway (Nambu et al., 2002)

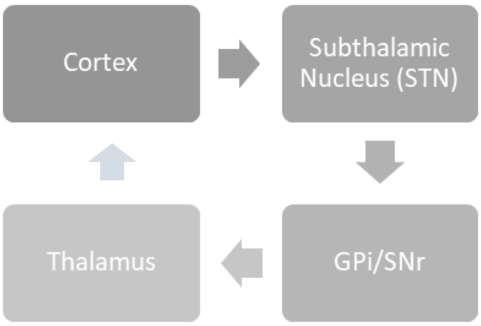


Figure 1. Illustration of the direct, indirect and hyperdirect pathways of the Basal Ganglia

The effect of dopamine differs according to the pathway's apparent function, with it indicated to be excitatory to the D1 receptors housed primarily within the direct pathway (leading to an increase in facilitatory, "Go" signals) and inhibitory to the D2 receptors residing primarily in the indirect pathway (leading to a decrease in inhibitory, "No Go" signals; Frank, 2005). In the direct pathway, there is evidence to suggest that dopamine, via D1 receptors, has the effect of amplifying the strong/relevant signal whilst dampening the weak/extraneous ones. In the indirect pathway meanwhile, the influence of dopamine is – through its inhibitory influence via D2 receptors – to effectively 'release the brake' and allow the system to move from its resting state of "No Go" to "Go", and the action selected via D1 receptor activity to be executed (Frank, 2005). Importantly this system is – through a short term alteration in dopamine levels driven by feedback – indicated to be able to learn, enabling the appropriate response to be selected even if it is not the most salient (Frank, 2006). The purported function of the hyper-direct pathway is rapid inhibition of areas of the thalamus and cortex, including those linked to the action that is to be initiated (Nambu et al., 2002). This, it is proposed, provides time for the correct motor response to be selected, with the strength of the "No Go" signal sent by the STN (via the hyperdirect pathway) linked to the number of competing alternatives activated (Frank, 2006).

From this model, it is easy to see how altered dopaminergic innervation may influence movement selection and initiation. And, whilst ongoing questions regarding the exact mechanisms underlying the 'classical' motor symptoms of PD remain (particularly in relation to tremor; Rodriguez-Oroz et al., 2009 - see also Jellinger, 2012), their presence in the PD symptom profile has been linked to basal ganglia dysfunction (Jellinger, 2012; see also Frank, 2006, with regards to PD tremor particlarly).

Although historically associated exclusively with motor control, the basal ganglia are now known to be involved with a number of other functions – including learning (particularly habit learning), cognitive functions, and emotions – through five distinct circuits: the motor loop, the oculomotor loop, two prefrontal associative circuits (the dorsolateral prefontal loop and the lateral orbitofrontal loop) and the limbic loop (Alexander & Crutcher, 1990; DeLong & Wichmann, 2007; Harris, 2011; Lanciego et al., 2012; Middleton & Strick, 2000). The basal ganglia nuclei show specialisms, with the putamen primarily associated with movement (although also linked with habit learning), the caudate linked primarily with eye movements and cognitive functions and the ventral striatum linked with emotions and reward based behaviour (Barone, 2010; Lanciego et al., 2012 – see also Galvan, Devergnas, & Wichmann, 2015, and Harris, 2011).

As Frank (2006, p. 1120) discusses, evidence would suggest that the basal ganglia pathways involved in cognitive functioning are "strikingly similar" in their arrangement to the motor circuit (see also Rodriguez-Oroz et al., 2009, for illustration). A series of computational frameworks have successfully modelled basal ganglia function in various executive processes (Frank, Loughry, & O'Reilly, 2001; Hazy, Frank, & O'Reilly, 2007; Wiecki & Frank, 2013), decision making (Frank, 2006), and learning (Frank, 2005). Within these circuits dopamine has been linked to cognitive control and, within the striatum more particularly, to cognitive flexibility (Cools & D'Esposito, 2011; see also Frank et al., 2001); indeed, the hypothesised effect of reduced dopamine within the striatum – i.e., cognitive inflexibility – has been seen repeatedly in PD, as evidenced through performance within set-shifting tasks, for example (Cools & D'Esposito, 2011). In accord with hypotheses developed from knowledge of basal ganglia motor circuit functioning, this cognitive flexibility has been related to the selective gating of task relevant information and inhibition of competing, irrelevant alternatives (Cools, Barker, Sahakian, & Robbins, 2001b; Van Schouwenburg, Den Ouden, & Cools, 2010)[1].

From this understanding of the involvement of the basal ganglia in both motor and cognitive control, broader impact of altered basal ganglia functioning – through reduced dopaminergic innervation – can also be considered. To take language as a pertinent example, if it were assumed that the same networks involved in producing movement/action are involved in the conceptual representations of those same actions, processing reliant on those representations being intact – e.g., lexical-semantic processing – could be hypothesised to be vulnerable to basal ganglia dysfunction. Equally, lexical processing which places greater demands on executive control processes could similarly expect to be implicated. And, indeed, as will be considered in greater depth within Sections 1.2.3 and 1.2.4, both the processing of single words which place greater cognitive demands and have a greater degree of 'action' associated with their meaning (i.e., verbs), and the processing of complex sentences – whether that complexity arises from syntactic or pragmatic demands – have been shown to be vulnerable in PD.

Lewy Body Pathology

Lewy body pathology has been proposed to progress in a predictable pattern (Braak, Ghebremedhin, Rüb, Bratzke, & Del Tredici, 2004). This pattern, however,

[1] Whilst not of primary consideration within this thesis, note that the role of the BG in the control of eye movements (saccades) has similarly been related to selection and inhibition (see Hikosaka, Takikawa, & Kawagoe, 2000).

does not always appear to match clinical symptoms. Some patients do appear to conform to the stages proposed by Braak; namely those with a long disease progression, which begins young and is associated predominantly with motor symptoms and dementia in the later stages (Rietdijk, Perez-Pardo, Garssen, van Wezel, & Kraneveld, 2017). For many however, there seems to be little relationship between the stages proposed by Braak and clinical severity (Burke, Dauer, & Vonsattel, 2008). There are, too, examples of PD cases where no Lewy body pathology has been observed (Burke et al., 2008; Wu, Le, & Jankovic, 2011).

It also remains unclear exactly how Lewy body pathology is contributing to the degeneration seen in PD. Studies do not appear to support the assumption that it is their presence which causes cell loss, leading to questions regarding whether it is, indeed, cell death causing the degeneration seen in PD at all, or whether such degeneration may instead be caused by the gathering of smaller clumps of alpha-synuclein at synaptic junctions (Schulz-Schaeffer, 2010). Other processes potentially involved in the neuronal degeneration seen in PD include oxidative stress, a rise in iron content, alterations in the processing of proteins and neuroinflammation (Hirsch, Vyas, & Hunot, 2012; Rocha, De Miranda, & Sanders, 2017).

Diagnosis, Prognostic Markers and Symptomology

There is currently no objective test for PD and, whilst there are positive signs that blood biomarkers may be a means through which PD and other parkinsonian disorders can be differentiated (Hansson et al., 2017), diagnosis is currently largely dependent on clinical presentation (Jankovic, 2008). These clinical markers have traditionally been the presence of the cardinal motor symptoms outlined above, however there is increasing evidence to suggest that a number of non-motor symptoms can appear early in disease progression – in some cases, long before the onset of the 'classic' motor symptoms themselves (Chaudhuri et al., 2006; Goldman & Postuma, 2014). This has called into question the often assumed idea that the cardinal motor symptoms, currently used as diagnostic markers of the condition, can be classified as 'early symptoms' of the condition (Lang, 2011). Knowledge of the symptoms associated with this 'premotor stage' (such as altered olfactory functioning; Stern, Lang, & Poewe, 2012), could prove useful in the development of a biomarker for the condition although are, in themselves, unlikely to possess the sensitivity or specificity for such a role (Haas, Stewart, & Zhang, 2012; Lang, 2011).

PD is, as already alluded to, increasingly being recognised as a multi-system disorder (Jellinger, 2012). Nonetheless, the non-motor symptoms (and, particularly, treatments for them) of the disorder remain relatively under-researched, despite being shown to have a significant effect on quality of life (QOL; Chaudhuri, Odin, Antonini, & Martinez-Martin, 2011; Todorova, Jenner, & Ray Chaudhuri, 2014). The non-motor factor of specific interest within this thesis is cognition, with an emphasis on language functioning.

As has already begun to be touched upon, there is increasing evidence to suggest that language function may be impacted upon by PD, however many questions remain regarding the root of this language alteration; crudely, whether the language impairment is linguistic in nature, or reflects an alteration in broader, supporting cognitive functions. As a consequence of the way in which this question is framed, language functioning has been considered somewhat separately to other cognitive functions throughout this discussion.

The first section provides a background to cognitive alteration in PD more broadly, with minimal focus on language processing specifically. This paves the way for the two following sections, which focus on single word and sentence and discourse level language processing in PD, respectively - organised according to the various hypotheses proposed to explain the observed language alteration and the evidence supporting them. The chapter concludes with an overall summary of the literature discussed, and an overview of the current gaps within the literature which this research aims to address. From this springboard proceeds details of the aim of this study, and the research questions and accompanying hypotheses being explored.

1.2.1 Cognitive Alteration in PD

There is ever increasing evidence to suggest that many individuals with PD will experience a degree of cognitive alteration throughout the course of the condition, in some instances from the early stages (e.g. Aarsland, Andersen, Larsen, Lolk, & Kragh-Sørensen, 2003; Broeders et al., 2013; Domellöf, Ekman, Forsgren, & Elgh, 2015; Muslimović, Post, Speelman, De Haan, & Schmand, 2009)[2]. Findings from incident studies indicate that somewhere in the region of 50% of individuals with PD show a degree of cognitive alteration – as measured through scores on a battery of neuropsychological tasks – upon presentation (Poletti et al., 2012). Further, over the course of 3-5 years, approximately half of individuals with PD were indicated to have demonstrated a degree of cognitive decline (again according to performance on a battery of neuropsychological tasks) greater than that of matched, healthy controls (Broeders et al., 2013; Muslimović et al., 2009). In other words, the rate of cognitive alteration seen in approximately half the PD group was significantly greater than that seen in typically ageing individuals over the same time period – suggesting that

[2] See also Aarsland, Brønnick, et al. (2011); Biundo, Weis, and Antonini (2016); Dubois and Pillon (1996); Jellinger (2013); Kehagia et al. (2013); Svenningsson, Westman, Ballard, & Aarsland (2012); Weil, Costantini, and Schrag (2018); Yarnall, Rochester, and Burn (2013) for review and discussion.

changes in cognition occur at a faster rate in PD than as a part of typical ageing (Muslimović et al., 2009).

Partly in response to findings indicating that approximately 80% of individuals with PD will ultimately develop dementia (Aarsland et al., 2003; Hely et al., 2008), mild cognitive impairment (MCI) has, in recent years, been introduced as a construct in PD; cemented through the development of diagnostic criteria[3] (Goldman et al., 2018; Litvan et al., 2011). And, indeed, whilst the relationship between MCI and dementia in PD appears to be a complex one, there is an indication that certain MCI profiles may have clinical utility in predicting the trajectory of decline towards dementia (Goldman et al., 2018; Kehagia, Barker, & Robbins, 2010). Findings from Kempster, O'Sullivan, Holton, Revesz, and Lees (2010) would suggest that, in instances within which dementia is part of an individual's profile, it presents at a predictable point within the disease progression; namely the late – sometimes referred to as terminal – stage. An interesting finding from this study is that whilst age did not appear to influence the rate of cognitive and physical decline in this final stage, it did influence the point at which this stage was reached, with those diagnosed younger showing a slower progression during the early and middle phases than those who were diagnosed with the condition at an older age (Kempster et al., 2010). This finding is somewhat akin to that of Aarsland, Muniz, and Matthews (2011) who observed what they described as an 'inflection' point: the point at which the rate at which individuals' general cognitive functioning (as measured through the Mini Mental State Examination [MMSE]; Folstein, Folstein, &

[3] The criteria and component levels of assessment are tiered. Level 1 assessment is designed with speed and brevity in mind – but as a consequence, offers a lesser degree of diagnostic certainty. Level 2 criteria, through providing a more detailed picture, enables the categorisation of MCI into subtypes, according to the cognitive domain affected, and whether the alteration is single or multi-domain (Goldman et al., 2018; Litvan et al., 2011).

McHugh, 1975) was declining increased. By both sets of authors, this rate of decline was discussed in relation to the development of Lewy body pathology within the cortex.

The heterogeneity of the cognitive alteration which can accompany PD is becoming increasingly evident, with a number of studies reporting alteration in visuospatial functioning, language and memory (Broeders et al., 2013; Muslimović et al., 2009; Poletti et al., 2012) as well as the executive impairment more commonly associated with the condition (see Dirnberger & Jahanshahi, 2013; Kudlicka, Clare, & Hindle, 2011 for comprehensive reviews regarding executive functioning in PD). The degree to which the alterations in visuospatial functioning, language and memory may actually be underpinned by alteration in executive function, however, as opposed to reflecting alteration in the domains of visuospatial functioning and memory *per se* remains a matter of debate (Brønnick, Alves, Aarsland, Tysnes, & Larsen, 2011; Dubois & Pillon, 1996). Executive functions can be conceptualised as attentional processes important for the co-ordination and supervision of other cognitive processes. Three primary executive functions (which, whilst separable, remain highly correlated with one another) have been identified: set shifting (the ability to flexibly move and direct attention between mental sets or tasks), inhibition (the ability to constrain and override automatic or prepotent responses) and updating (the ability to update the information held in short-term ["working"] memory, in relation to the needs of the task in hand) (Miyake et al., 2000; see also Friedman & Miyake, 2017 for discussion).

As alluded to in Section 1.2, executive dysfunction in PD has been linked primarily to an alteration in the functioning of frontal-striatal circuitry, reflective of dopaminergic depletion (Aarsland, Brønnick, & Fladby, 2011; Kehagia, Barker, & Robbins, 2010; Kehagia, Barker, & Robbins, 2013). The relationship however, between dopamine levels and performance in experimental tasks tapping into components of working memory and executive control is not a straightforward one (Cools & D'Esposito, 2011). Within their review, Cools and D'Esposito (2011) describe a 'U-shaped' relationship between levels of dopamine and executive functioning, with both too little and too much dopamine having the capacity to diminish cognitive performance, dependent on the process under investigation and underpinning brain region. Furthermore, an additional element of individual variability comes into play, such that the influence of an alteration in dopamine levels will depend on the base level of each individual (Cools & D'Esposito, 2011). In PD, this effect has been discussed in relation to the 'dopamine overdose hypothesis' (Kehagia et al., 2013).

The 'dopamine overdose hypothesis' relates to the fact that the degeneration of dopaminergic neurons associated with PD is both selective and uneven in nature (Brichta & Greengard, 2014). In the early course of disease progression especially, there is a noticeable imbalance, with some circuits subject to greater dopamine depletion than others (Cools, Barker, Sahakian, & Robbins, 2003; Vaillancourt, Schonfeld, Kwak, Bohnen, & Seidler, 2013). As a result, dopaminergic therapy administered early in disease progression may, whilst alleviating symptoms relating to certain circuity (such as cognitive inflexibility and set shifting) through the remediation of dopamine loss within that circuit, overdose another, leading to reduced performance (Cools, Altamirano, & D'Esposito, 2006; Cools, Barker, Sahakian, & Robbins, 2001a; Cools et al., 2003; Cools, Lewis, Clark, Barker, & Robbins, 2007; MacDonald et al., 2011; Vaillancourt et al., 2013 - see also Kehagia et al., 2013).

Whilst evidence suggests that executive dysfunction is common in PD, even at the early stages of the condition, there is evidence to suggest that the rate of decline in executive function ability over time – as compared with that of other cognitive domains – appears relatively slow (Muslimović et al., 2009). Somewhat relatedly, work concerned with the identification of factors which separated individuals diagnosed with MCI as part of their PD profile who did or did not progress to dementia within a period of 5 years, found no difference in baseline measures of executive function (as measured through performance within the Wisconsin Card Sorting Test) or working memory between the two groups (Domellöf et al., 2015). The authors did however report a significant difference in measures of episodic memory, visuospatial functioning, semantic fluency and mental flexibility[4] between those individuals who did and did not convert to dementia (Domellöf et al., 2015).

A similar pattern was observed within both the longitudinal Cambridgeshire Parkinson's Incidence from GP to Neurologist (CamPaIGN) study (Williams-Gray et al., 2009, 2007; Williams-Gray et al., 2013) and a 16 year cohort study conducted by Hobson and Meara (2015). In the former, reduced performance in more posterior, cortically based functions (as measured through pentagon copying and semantic fluency) was found to predict the development of dementia, whilst patterns of frontal-executive dysfunction were not (Williams-Gray et al., 2009, 2007; Williams-Gray et al., 2013). Similarly, Hobson and Meara (2015) found performance within tasks assessing semantic fluency, figure drawing/copying and visuospatial functioning to be predictive of progression from MCI to dementia. Relatedly, a study conducted by Santangelo et al. (2015) observed that the individuals with PD more likely to revert

[4] It should be noted here that the authors assessed attention and mental flexibility' using the Trail Making Task (Army Individual Test, 1944, as cited in Reitan, 1955); a task which can also be found used to assess set shifting, a core executive function.

back to normal cognition - following a diagnosis of MCI at the previous time point – were those who had higher scores in visuospatial functioning but lower scores in tasks tapping executive functioning at baseline. There could be a number of reasons for this reversion to typical cognition, including alteration in the effect of dopaminergic medication. Having said that, reversion to typical cognition from MCI is fairly commonly reported in the general population (e.g., Koepsell & Monsell, 2012); thus the difference in the patterns of cognitive functioning at baseline between those who did and did not revert to typical functioning could be of prognostic importance.

These patterns are interesting to consider – albeit somewhat muddied by the questions arising regarding the degree to which alteration in executive control may be underpinning the observed changes in other cognitive domains (Brønnick et al., 2011). As Williams-Gray et al. (2007) discuss at length however, the fact that semantic fluency appeared to predict a faster decline to dementia whilst phonological fluency did not would suggest that it is the semantic element of the task – as opposed to the frontal, executive requirements common to both – which was at the root of the difference in performance between those who did and did not progress to dementia. This conclusion is somewhat supported by the findings of Reid, Hely, Morris, Loy, and Halliday (2011). Upon comparing the neuropsychological profiles of individuals who had developed dementia earlier (5-10 post PD diagnosis) as compared with later (10 years+ post PD diagnosis), these authors found that, at the time of dementia onset, a greater degree of vocabulary impairment was present in those individuals who had developed dementia 5-10 years post diagnosis (Reid et al., 2011). This finding could suggest that an earlier decline in cognitive functioning (to dementia) is heralded by a reduction in linguistic ability; a pattern discussed by the authors in relation to the patterns of atrophy seen in Alzheimer's disease – and further supported by the findings of Weintraub et al. (2012), which through a process involving spatial mapping, found that the presence of patterns of atrophy typically associated with Alzheimer's Disease was associated with cognitive decline in individuals with PD.

It is interesting, however, to consider these findings in relation to the aforementioned study conducted by Domellöf et al. (2015). These authors did not find a significant difference in vocabulary scores at baseline between those with MCI who had converted to dementia within the five year follow up period and those who had not. Further, this was observed despite there having been a significant difference in naming performance *collectively* between those individuals with PD-MCI at baseline as compared with those individuals showing no cognitive alteration (Domellöf et al., 2015). Due to the aims of that study, it is not possible to establish whether the vocabulary scores of those individuals with PD-dementia were reduced as compared with those individuals who had not converted from PD-MCI at the 5 year point. Bearing this limitation in mind, one could tentatively propose that whilst differences in vocabulary scores at baseline – in contrast to measures of semantic fluency – may not be sensitive predictors of dementia development, the rapidity of the decline within this function across the next five years may be a valid predictor of the likelihood of early dementia development. A proposal which, in turn, presents a number of questions regarding what it is about semantic fluency specifically which appears able to accurately predict decline to dementia at baseline, when other tasks also reliant on intact semantic processing may not show the same sensitivity.

Whilst the previously reported finding suggesting that phonological fluency was not a predictor of cognitive decline points away from executive control being a sensitive predictor of cognitive decline per se, it is interesting to consider whether it is the combination of semantic alteration and a degree of executive alteration which is particularly sensitive in predicting a faster rate of cognitive decline (towards dementia). As part of their study, Santangelo et al. (2015) looked both at individuals who progressed from MCI to dementia, and those who progressed from typical cognition at baseline to MCI, at the follow up points. The authors found that, of the neuropsychological tests performed at baseline, it was reduced performance within the Stroop interference test which most reliably predicted the development of MCI at four years (Santangelo et al., 2015). These findings are, in many respects, in line with those reported by (Williams-Gray et al., 2007). Collectively, findings from these two studies would suggest that frontal executive deficits appear to result in slower cognitive decline – as evidenced through the development of MCI at the four year follow up, in Santangelo et al.'s (2015) study – than more posterior deficits, which heralded the development of dementia 3.5 years following disease onset in Williams-Gray et al.'s (2007) study. They also present, however, the interesting possibility that a continuum may exist between early, altered inhibitory control, the later development of reduced performance within semantic fluency tasks – reflecting additional impairment in the more posteriorly located semantic processes additionally required for this task – and the development of dementia.

Santangelo et al. (2015) did not include semantic fluency as part of their neuropsychological battery and it therefore cannot be determined whether those individuals who had developed MCI may also have demonstrated reduced semantic fluency performance, either at baseline or at the four year follow up point (i.e., as part of their MCI profile). What is known, however, is that of those individuals who developed MCI at four years – predicted by reduced performance in the Stroop task at baseline – all had altered visuospatial processing as part of their MCI profile. This study extended no further, thus it is not possible to establish the rate at which these individuals may have progressed from MCI to dementia. Nonetheless, again, this finding points towards a potential link between performance within the Stroop task specifically – at a subthreshold level – and the development of MCI characterised by traits which previous studies have suggested may herald a faster rate of decline towards dementia.

This hypothesised link too raises an important point regarding the assessment of executive functioning in PD. It is – both amongst the studies focussed upon here, and more broadly within the literature – relatively common to find 'executive' or 'frontal' functioning referred to en masse; whilst simultaneously finding a lack of consistency in the tasks being used to assess such functioning. This not only limits understanding of exactly what aspects of executive functioning are impaired in the studies concerned, but also provides the potential for findings to appear contradictory, when in fact such difference is reflective of the task being used, the particular executive component and other cognitive demands within it. In light of the aforementioned finding to suggest that alteration in inhibitory control may represent the start of a particular trajectory of cognitive decline, tapping into the three executive functions separately appears warranted.

The difference in patterns of decline between those individuals whose profile is characterised by more posterior versus more frontal cognitive deficits has led to the formation of the 'dual syndrome hypothesis' (Kehagia et al., 2013). In line with findings to indicate that particular motor profiles – namely the presence of postural and gait dysfunction (Williams-Gray et al., 2009, 2007; Williams-Gray et al., 2013 - see also Poletti et al., 2012) – are additionally predictive of rates of cognitive decline, two broad syndromes have been proposed. The first is characterised by a pattern of frontal-striatal cognitive alteration and a tremor dominant phenotype which, whilst susceptible to overdose, responds to dopaminergic therapy (Kehagia et al., 2013) In contrast, the second profile is characterised by prominent axial symptoms alongside deficits in visuospatial functioning and semantic fluency – for which, in contrast to the first syndrome, cholinergic treatment may prove to be of greater benefit (Kehagia et al., 2013). There is, as outlined throughout this discussion, room for this theory to be elucidated, particularly in relation to understanding whether any markers, such as an alteration in inhibitory control, exist which may precede and be able to predict the development of more posterior deficits. Whether, too, for those individuals who present with altered semantic fluency and visuospatial functioning at baseline, these markers present during the prodromal phrase – would be interesting to examine.

In summary, cognitive alteration is common in PD. Whilst executive dysfunction is frequently reported, the pattern of cognitive alteration which may present is heterogenous and, furthermore, there is notable variation in both the degree of cognitive impairment experienced, and the rate of decline. In light of findings indicating that up to 80% of individuals with PD will ultimately go on to develop dementia, interest in the identification of factors which may predict cognitive decline has increased. And, although MCI as an overall construct has limited predictive validity in PD, there is an indication that the identification of subtypes of MCI may be beneficial in identifying those individuals likely to show a faster rate of cognitive decline towards dementia.

1.2.2 Language Alteration in PD

When considering the communication changes associated with PD, thoughts typically turn first to dysarthria. This is perhaps unsurprising given that the condition is estimated to affect approximately 70-90% of individuals diagnosed with PD (Ho, Iansek, Marigliani, Bradshaw, & Gates, 1998; Logemann, Fisher, Boshes, & Blonsky, 1978; Miller et al., 2007). It is increasingly understood however – as evidenced both through experimental procedures (see Altmann & Troche, 2011; Auclair-Ouellet, Lieberman, & Monchi, 2017; Holtgraves & Cadle, 2016 for review) and reported by individuals themselves (Miller, Noble, Jones, & Burn, 2006) that communication can be much more broadly affected by PD. More specifically, altered performance has been observed in the comprehension of syntactically and pragmatically complex sentences, lexical-semantic processing (particularly affecting verbs) and sentence and discourse production (see Altmann & Troche, 2011; Auclair-Ouellet et al., 2017; Holtgraves & Cadle, 2016, for review).

Studies assessing comprehension have highlighted difficulties in the processing of specific complex syntactic structures (e.g. Angwin, Chenery, Copland, Murdoch, & Silburn, 2005; see also Auclair-Ouellet et al., 2017; Holtgraves & Cadle, 2016 for review) as well as pragmatic impairments, as shown through a reduced ability to comprehend metaphor (Monetta & Pell, 2007), and irony (Monetta, Grindrod, & Pell, 2009), and to perceive the emotional information signalled through prosody and correctly infer speaker intention (Pell et al., 2014 - see also Miller, 2017 and Pell & Monetta, 2008 for review and discussion). Both the altered comprehension of complex syntactic structures and structures which are 'complex' due to their pragmatic demands (e.g., metaphor) have been linked to other cognitive processes, such as set-shifting and working memory (see Auclair-Ouellet et al., 2017 and Holtgraves & Cadle, 2016 for review). Both, too, may be linked to prosody perception, whether that be the recognition of speaker intention or utilising prosodic information to aid grammatical parsing. Whilst, as Carlson (2009, p. 1197) neatly expresses, "prosody is not a silver bullet for parsing which unilaterally makes sentences unambiguous…", it remains possible that altered prosody perception –

via reduced appreciation of prosodic cues – may be contributing to the altered comprehension of complex syntactic structures in PD (see Miller, 2012, for discussion regarding ambiguity resolution). And, indeed, work by Lee, Grossman, Morris, Stern, and Hurtig (2003) would suggest that individuals with PD may show reduced sensitivity to unbound grammatical morphemes – such as 'that' – which can play an important role in signalling clausal structure and may be supported by prosodic marking.

Alongside the patterns of altered comprehension observed, a selective verb processing deficit has also been observed in PD. In Section 1.2, the role of the basal ganglia in both motor and cognitive processing was considered. These two characteristics – i.e., the requirement of intact motor representations and the placement of greater executive control demands – conflate on the word class of verbs. Verbs typically denote actions and, through their greater lexical complexity as compared with nouns, are thought to place greater demands on executive control processes (Cousins, Ash, & Grossman, 2018). As touched upon in Section 1.2, from what is known about basal ganglia circuitry, one could predict that the word class of 'verb' would be vulnerable to basal ganglia dysfunction; either potentially as the result of degraded semantic representations linked to damaged motor circuitry and/or as a result of impaired executive functioning. As will be explored further in the following sections, exactly what is underpinning the verb alteration seen in PD – and, somewhat by extension, what role the basal ganglia occupy in language processing – remains an ongoing question. Gaining a greater understanding of the verb processing alteration in PD would be elucidating not only in terms of understanding how to target therapeutic intervention for individuals with PD, but in terms of our understanding of language networks more broadly. Indeed, as authors such as Silveri et al. (2018) outline, the pathology of PD, for the reasons just outlined, appears particularly suitable for exploration concerned with increasing our understanding of verb processing.

With regards to sentence and discourse production, alteration in both language *form* (e.g., Troche & Altmann, 2012) and language *use* – as measured for example through narrative cohesion (Ellis, Crosson, Gonzalez Rothi, Okun, & Rosenbek, 2015), turn-taking and prosody (considered a pragmatic impairment as prosody plays an important part in conveying emotion and speaker intention; McNamara & Durso, 2003) – have been observed (see Altmann & Troche, 2011; Auclair-Ouellet et al., 2017; Holtgraves & Cadle, 2016 for review). Importantly, findings would suggest that alterations in language and pragmatic processing can both present as part of the PD profile separate to any accompanying dementia (e.g., Bocanegra et al., 2015; McNamara & Durso, 2003; Troche & Altmann, 2012). This creates a number of questions regarding what is underpinning such difficulties, particularly in light of the findings to suggest that the alteration seen may be linked to other, supporting cognitive processes (e.g., McNamara & Durso, 2003; Troche & Altmann, 2012) but not necessarily entirely explained by them (Troche & Altmann, 2012).

Research into language alteration in PD, although expanding, remains relatively limited and somewhat divided, with research into single word processing largely separate from that looking at sentence production. This appears in part attributable to the nature and aims of the research. Much of the research relating to single word and syntactic processing particularly appears to be led by hypotheses relating to the neuroanatomical underpinnings of language – particularly whether any involvement of subcortical structures in language processing is direct or indirect - and theories of embodied cognition. In contrast, studies investigating sentence and discourse production (from herein referred to collectively as ‘complex’ language production) tend to be more exploratory – investigating the language changes which might be associated with PD as opposed to using the pathology of PD to test hypotheses relating to subcortical structures. It is partly for this reason perhaps, as will be explored further in the following sections, that noticeable gaps present in the evidence base.

Bearing in mind the current research landscape, this review has been divided broadly into two parts, roughly in line with strands of research just described. Current evidence regarding single word processing in PD will first be discussed, with particular reference to the theories proposed to account for the observed patterns of impairment. This will lead into a section concerned with complex language processing, including consideration of studies which have investigated syntactic processing through comprehension studies. This will then pave the way for a discussion of the findings relating to complex language production with, again, particular focus paid to theories regarding why such alterations may be presenting.

Whilst, as outlined above, various pragmatic abilities have been indicated to be impaired in PD, the focus within this study is on lexical (language) processing – specifically, single word and sentence level processing – and the theoretical background targeted accordingly. Thus, whilst the pragmatic difficulties which can present in PD are fully acknowledged, they are not explored in any further depth within this thesis.

1.2.3 Single word processing in PD

Single word processing in PD has been explored through a variety of means, including **naming** (e.g., Bertella et al., 2002; Bocanegra et al., 2017, 2015; Cotelli et al., 2007; Herrera & Cuetos, 2012; Herrera, Rodriguez-Ferreiro, Cuetos, Rodríguez-Ferreiro, & Cuetos, 2012; Rodríguez-Ferreiro, Menéndez, Ribacoba, & Cuetos, 2009; Salmazo-Silva et al., 2017; Silveri et al., 2012), **verbal fluency** (e.g., Herrera, Bermúdez-Margaretto, Ribacoba, & Cuetos, 2015; Herrera, Cuetos, & Ribacoba, 2012; Piatt et al., 1999; Rodrigues et al., 2015; Salmazo-Silva et al., 2017; Signorini & Volpato, 2006), **word generation** (e.g., Crescentini, Mondolo, Biasutti, & Shallice, 2008; Herrera & Cuetos, 2013; Péran et al., 2003) and **lexical decision** tasks (e.g., Boulenger et al., 2008). Whilst some variation in findings is evident across the literature, the general picture which emerges is that single word processing is vulnerable in PD, with verb processing disproportionally affected.

Following early findings suggesting a dissociation between verb and noun processing in PD, investigation has focused on developing an understanding of *why* this difference is presenting. Various explanations have been put forward, from the pattern reflecting the grammatical difference between the word classes (Péran et al., 2003), the semantic difference between verbs and nouns (i.e., actions versus objects) and, by extension, the involvement of motor areas in the semantic representations of actions (e.g., Bocanegra et al., 2017; Boulenger et al., 2008) and alteration in retrieval and selection processes, with the deficit in verb processing reflecting the increased options associated with verbs as compared with nouns (e.g., Crescentini, Mondolo, et al., 2008; Silveri et al., 2018). Crudely, these hypotheses can be divided according to whether they relate to inherent differences between nouns and verbs (whether that is considered along semantic or grammatical lines) or are reflective of an alteration in the executive control processes necessary for effective retrieval. Considered in this way it is clear that, whilst the word class and semantic hypotheses are to some degree in direct competition, it is perfectly possible for the selection hypothesis to present in tandem with either, or potentially both, of them (see Silveri et al., 2018 for discussion). Thus, the question too is to what degree alteration in lexical representations and/or retrieval may be underpinning the changes observed in behavioural studies, and whether any differences in findings can be explained by differing task demands and consequent difference in the pressures placed on the system (for example, under high cognitive demand, could any subtle effect of action content be ‘hidden’ by general retrieval difficulties?). This, too, feeds into the broader question of whether the verb alteration seen is reflective of more domain specific cognitive alteration or are ‘linguistic’ in nature – and, by extension, whether any role of the basal ganglia circuitry in language processing is specific to language processing per se. Before considering these hypotheses in greater depth, an overview of the development of current understandings of verb and noun processing are presented.

1.2.3.1 The evolution of theories underpinning the processing differences between nouns and verbs

Interest into the way in which words of different grammatical class (namely nouns and verbs) are processed has a long history, stemming back to the discovery of a double dissociation between verb and noun production in individuals with aphasia (see Crepaldi et al., 2013; Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011; Mätzig, Druks, Masterson, & Vigliocco, 2009; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011 for review and discussion). Early work, such as that by Damasio and Tranel (1993), point towards verb retrieval being reliant on (left) frontal networks, with noun processes conversely located in (left) temporal regions. A number of subsequent lesion studies have provided fairly strong support for involvement of the temporal lobe in noun retrieval (although there is some discrepancy as to the exact location in the temporal area; Crepaldi et al., 2011). In contrast, the picture for verb retrieval is somewhat more mixed, with a number of anterior areas, including the frontal and parietal areas, and the basal ganglia, appearing to be implicated. The finding that no singular brain area appears to be consistently associated with verb retrieval could indicate that the process is served by an extended fronto-temporo-parietal network (within which subcortical structures are also implicated). As evidenced through findings to suggest an absence of verb production deficits in cases of both frontal and parietal lesions, such a network must be adaptable enough to accommodate selective damage within it, and/or contain a number of specialised circuits (Crepaldi et al., 2011).

Another important consideration is the functional level at which the noun/verb impairments are occurring. As a number of authors have discussed, the noun/verb double dissociation can reveal little, either functionally or in terms of anatomical correlates, if the noun naming difficulties seen are reflective of a breakdown at one level of processing and verb naming at another (Crepaldi et al., 2011; Mätzig et al., 2009). With this in mind, in the latter part of their aforementioned paper, Crepaldi et al. (2011) reviewed the available evidence from imaging and electrical stimulation studies involving neurotypical young adults according to level of processing (as measured through the task employed). In response to the observed lack of consistency in terms of activation patterns within tasks, the authors conclude that the imaging studies examined do not support the presence of specialised sub-circuits within a wider fronto-temporal-parietal network, as previously proposed. Neither do they support the verb/noun frontal/temporal dichotomy, with only half the studies considered reporting the activation of frontal areas in verb processing whilst, conversely, a noticeable number finding the activation of frontal areas in the production of nouns. It is important to note too – as discussed by the authors – that whilst many of the studies reporting this latter finding involved manipulable 'tool' nouns, activation of this area was not confined to such nouns, with activation also seen in studies not involving this category of nouns (Crepaldi et al., 2011). These findings combined lead the authors to conclude that verb and noun processing is not segregated and clustered in the ways previously proposed; rather that the processing of both word classes takes place within a predominantly shared network, within which smaller circuits differentially supporting noun and verb processing are 'interleaved' – so closely in fact that in the majority of cases, the spatial resolution of fMRI would not be sufficient to detect them (Crepaldi et al., 2013, 2011).

A somewhat different conclusion was reached however in a separate review of the topic (Vigliocco et al., 2011); reflective potentially both of the angle from which the review was approached, and the broader evidence base within which the imaging studies were considered (it should be noted too, that this latter review included a number of imaging studies not included in the former review). Here, the authors were concerned particularly with considering the confound between semantics and grammatical class; in other words, the degree to which any influence of word class was reflective of the inherent semantic difference between nouns and verbs (Vigliocco et al., 2011). Findings considered within the review suggested that, when the semantic difference between verbs and nouns (i.e., the fact that verbs typically denote actions whilst nouns denote objects) was controlled, any differences in activation patterns between the word classes all but disappeared. Thus, the authors concluded that the activation patterns evident in other studies – i.e., the often seen activation of premotor and motor areas, as well as the middle temporal gyrus – were indeed attributable to the semantic difference between nouns and verbs (Vigliocco et al., 2011). Thus, whilst arguing against the presence of neural segregation according to word class *per se*, the authors of this latter review do argue for segregation in terms of semantic knowledge (Vigliocco et al., 2011). Furthermore, in light of the patterns of activation observed, the authors take the findings to be largely supportive of the embodied view of cognition – the idea that, rather than being amodal, conceptual representations are grounded in action and perception.

What these differences in opinion may in turn tell us about verb and noun processing, and the way in which word classes are classified, is interesting to consider. A core difference in the two reviews under consideration here is the angle from which the evidence was approached. In their review, Vigliocco et al., (2011) were focussed particularly on establishing whether the verb/noun dissociation reflected a semantic confound. To that end, the authors identified and considered findings within which that confound has been controlled and compared them with findings from studies within which it had not. Whilst some heed was paid by the authors to the nature of the task, that was somewhat secondary. In contrast, Crepaldi et al. (2011) focussed primarily on examining the consistency of performance within different language tasks, with the aim of establishing whether the inconsistency evident from lesion studies may be reflecting different levels of processing. Crepaldi et al. (2011) did not control for semantic confound, such that findings from studies between which Vigliocco et al. (2011) were making comparisons, according to the way in which word class had been dichotomised, were considered *together* by Crepaldi et al. (2011). Thus, there is the potential that the differences in the conclusions reached reflect at least in part differences in the way in which the category of nouns and verbs was considered.

Embodied cognition

A number of theories of embodiment exist but, as Caramazza, Anzellotti, Strnad, and Lingnau (2014) outline, core to the majority is the idea that the same systems involved in perception and action production are implicated in the formation and subsequent retrieval of semantic knowledge. As such, the areas involved in producing actions would not only be involved in understanding the physical actions of another but also in the retrieval of semantic knowledge relating to actions. It is proposed that the same processes are enacted in all scenarios, whether that is action production perception, or semantic knowledge retrieval (Caramazza et al., 2014). For action (including action word) processing in particular, this hypothesis has been influenced heavily by mirror neuron theory; a theory established through the 'discovery' of mirror neurons in macaque monkeys (Caramazza et al., 2014; Hickok, 2010). In this 'pure' form, theories of embodiment appear at odds with both classical cognitive and distributional accounts of semantics, with the former purporting that concepts are stored in an entirely modality specific[5] form whereas in the latter it is assumed that conceptual representations are abstract symbols, entirely amodal in form (Binder & Desai, 2011; Caramazza et al., 2014; Mahon, 2015; Martin, 2016).

Given this divide in opinion, it is perhaps unsurprising that mirror neuron theory and 'strong'[6] views of embodiment have been heavily critiqued. This criticism, arising from imaging and behavioural studies, centres both around the lack of evidence available to categorically support a crucial, causal role of this mirror system in the processing of semantic knowledge and the fact that, if concepts were grounded solely in areas concerned with sensory-motor processing, significant impairments in processing all aspects relating to action would be anticipated in individuals with impairments affecting such areas, which again currently available evidence does not support (Binder & Desai, 2011; Caramazza et al., 2014; Hickok, 2010). Whilst current findings do not appear to support such strong forms of embodiment, the

[5] Modal/modality specificity – as Binder and Desai (2011, p. 527) define – "…refers to the representational format of the information". If modality-specific, the format of the representation is analogous to the input; for example, information learned about the appearance of a tree is stored in a visual format and would include factors such as size and colour.

[6] 'Strong' in this context is a somewhat relative term. As Mahon (2015) discuss, few have pushed for the strongest form of embodied cognition - i.e., idea of conceptual information being represented *only* in a modality specific format.

question nonetheless remains as to why motor cortex activity has been observed in the processing of action words.

One proposal is that activation in sensory and motor areas during semantic processing reflects a process of association and spreading activation. Under this proposal the activation of sensory-motor areas presents not as a necessary part of semantic knowledge retrieval but as an 'epiphenomenal' process during which, for example, a visual representation of the concept under consideration might be retrieved (see Caramazza et al., 2014; Hickok, 2010; Mahon, 2015 for discussion). Martin (2016), whilst also acknowledging the possibility that sensory and motor activation during semantic processing is somewhat peripheral, argues against such involvement being 'epiphenomenal', instead suggesting that it is a form of preparatory measure, reflecting the learnt experience that the recognition of certain objects is often followed by certain actions, for example. Both views are disembodied, in so far as they do not assume or purport that conceptual representations are modality specific and grounded in sensory/motor systems (Mahon, 2015). A second, somewhat alternative proposal is one which does see conceptual representation grounded in motor, sensory and emotion processes but as part of a larger heteromodal network within which representations are increasingly abstracted, centring on 'supramodal' convergence zones (Binder & Desai, 2011; Binder, Desai, Graves, & Conant, 2009; Meteyard & Vigliocco, 2018) or on an internal 'hub', to which the extended network serves as the spokes (Pobric, Jefferies, & Lambon Ralph, 2010; Ralph, Jefferies, Patterson, & Rogers, 2016). These convergence zones function to combine information, including, it is assumed, distributional linguistic information, through which information about a word's meaning is gleaned according to its relationship with other words (see Andrews, Frank, & Vigliocco, 2014 and Meteyard et al., 2018). They also function as a means through which to "…allow the efficient manipulation of abstract, schematic, conceptual knowledge that characterizes natural language, social cognition and others forms of highly creative thinking" (Binder & Desai, 2011, p.532) and enable the mapping "…between conceptual properties and phonological/orthographical information about words" that lies at the heart of lexical processing (Meteyard et al., 2018, p.7). It is important to note here, as Martin (2016) discuss, that there is no reason that this proposed network could not operate alongside activity in action areas also adopting a pre-emptive role.

Central, too, to this heteromodal network theory is the idea that access to all the 'parts' contributing to a conceptual representation are not necessarily automatically activated or required, depending on the task at hand and the context within which it is taking place (Binder & Desai, 2011; Kemmerer, 2015). That is not to say that any one of these modality specific contributors is not an essential part of the overall conceptual representation; rather that in circumstances under which an element of the overall conceptual representation had been damaged, successful understanding of that concept might still be able to be achieved, depending on the task at hand and the context within which is it conducted (Binder & Desai, 2011; Kemmerer, 2015). Furthermore, if we consider this context as an interplay of external and internal aspects, some degree of individual difference would be expected, depending on an individual's experience, and subsequently the means through which their conceptual representation has become established (Meteyard & Vigliocco, 2018). To take an example provided by the previously referenced authors (Meteyard & Vigliocco, 2018) one might expect a different pattern of brain activation during action comprehension if an individual has significant experience of carrying out that action (where one might expect activation in motor networks) as compared with someone whose knowledge of that concept has been established primarily through visual means (see also Watson, Cardillo, Ianni, & Chatterjee, 2013 for discussion).

This idea, commonly able to be found referred to as a model of ‘weak’ embodiment, presents somewhat of a middle ground between strong ‘embodied’ and ‘disembodied’ theories and, as such, appears able to bring together and reconcile many of the differences between such models (Andrews et al., 2014). This however, in turn, presents interesting questions as to *functionally* what distinguishes models which could be considered as ‘weakly embodied’ and theories which have approached the matter from the somewhat reverse perspective and might arguably be considered to be weakly disembodied. In ‘weak disembodiment’ models, conceptual representations are – as per ‘fully’ disembodied views – considered to be amodal, but are also considered to be “…necessarily interactive with sensory-motor information” (Martin, 2016, p. 983) such that “…the instantiation of a concept includes the retrieval of specific sensory and motor information” (Mahon & Caramazza, 2008, p. 68). The difference between models of weak embodiment and weak disembodiment – a prime example of which is the ‘grounding by interaction theory’ – appears primarily to be the distinction between how these representations are connected. In the weakly disembodied theory it is proposed that, whilst closely connected, the amodal conceptual representations are entirely separate from perceptual and action knowledge whereas, in the weakly embodied model, the two in effect are merged, with the supramodal convergences being the last layer of abstraction, in effect (see Binder & Desai, 2011 for excellent illustration).

There are questions, too, as to whether knowledge about a concept is stored directly *within* the motor and sensory cortices or are found located adjacent to and overlapping with such primary motor and sensory regions in, as Martin, (2016, p.980) describes, “..our *perception, action and emotion systems”* (Martin, 2016 p.

980; see also Mahon, 2015). It is interesting that, within their model, Martin (2016) propose that whilst the architecture which allows us to learn about a particular property of an (in this instance) object are located in the region within which the process would typically be expected to take place, they are not modality specific. To use their example, it has been shown that information about the form of objects, which would typically be expected to be obtained through visual means, is found in the same region in both individuals who have impaired and non-impaired vision; thus, whilst obtained through different inputs, information relating to the form of an object are stored analogously in individuals with and without sight (Martin, 2016).

In summary, whilst there is significant overlap between these proposed models of conceptual representation, some differences present with regards to how high level amodal or supramodal conceptual representations are connected with sensory and motor information and the way in which concepts are considered to be grounded; i.e., exactly where such information is housed and, relatedly, whether the conceptual information housed within sensory-motor systems is considered to be modality specific (an "…analog of the input"; Binder & Desai, 2011, p. 527) or form specific (Martin, 2016). The format that conceptual representations take is often discussed when considering theories of embodiment (i.e., whether such representations are modality specific) however as Martin (2016) has discussed, this knowledge is arguably of little practical significance. We do not yet have the ability or methods through which to establish the format such representations are taking and, until such a time that we do, the debate will remain unresolved (Martin, 2016). Thus, how 'useful' the consideration of format is in our understanding of semantic representation is called into question.

1.2.3.2 Verb processing in PD: the influence of semantics

As mentioned in the opening paragraph, the semantic difference between nouns and verbs – i.e., that nouns typically depict objects and verbs typically depict actions – is one theory proposed to account for the selective verb deficit observed in PD. Following an early finding to suggest that the observed verb naming difficulty in PD appeared to be semantic as opposed to phonological in nature (as reflected though intact repetition; Bertella et al., 2002) and against the backdrop of evidence emerging to suggest selective verb naming disruption in conditions which were primarily considered to be disorders of movement (e.g., Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Cotelli, Fatebenefratelli, & Calabria, 2006), findings began to be discussed in relation to hypotheses regarding the role of motor areas in conceptual representations; in other words, in relation to theories of embodied cognition.

For such a hypothesis to be confirmed there is a need, as authors such as da Silva, Machado, Cravo, Parente, and Carthery-Goulart (2014) have discussed, for a demonstrable difference in performance between verb *types* to be seen (i.e., a difference according to the level of action associated with the verb), in order for the potential confound of grammatical word class to be excluded. And, indeed, there is a body of evidence to this effect. For example, Bocanegra et al. (2017) compared the production of nouns which varied in their manipulability, and verbs which varied in their motion content, between individuals with PD an controls. The authors found that, whilst those individuals with MCI showed reduced naming accuracy in all conditions, in the individuals with PD non-MCI a deficit was limited to the production of high action verbs (Bocanegra et al., 2017). This finding is in line with those from a succession of studies led by Herrera, who also observed a differential effect of motor content, with higher action verbs appearing to be particularly vulnerable in PD

(Herrera et al., 2015; Herrera & Cuetos, 2012; Herrera, Rodriguez-Ferreiro, et al., 2012).

From the two of those aforementioned studies which included dopaminergic status as a variable, there was an indication too that this effect of motion interacted significantly with dopamine levels (Herrera et al., 2015; Herrera & Cuetos, 2012). Specifically, individuals *off* medication were found to respond more slowly to pictures depicting high motor content verbs (Herrera & Cuetos, 2012) and, in an action fluency task, found to produce a significantly lower number of high action verbs, as compared with controls (Herrera et al., 2015). Whilst cognitive status was not included as a variable in these latter studies, in all a cognitive screening procedure was employed, with no individuals involved in the study showing signs of MCI or dementia, according to the tools employed. Thus, collectively, these results point towards a high action/motion specific verb production deficit in the absence of broader cognitive alteration. This, combined with the reported impact of dopamine levels on high action verb processing, could be argued to evidence a specific role of the basal ganglia, via its role in motor networks, in lexical-semantic processing. Or, to put it another way, that the pathology of PD has a direct impact upon the conceptual processing of high action/motion verbs, due to degradation of motor information which forms a part of the conceptual representation.

Motor language coupling in PD has been examined more specifically, too, through studies exploring whether any action word deficit seen corresponds with the locus of individuals' motor impairment (Roberts et al., 2017) and through paradigms assessing motor response/language compatibility (Ibáñez et al., 2013). In this latter paradigm, of interest was the presence of an 'action-sentence compatibility effect' (ACE; Ibáñez et al., 2013). Individuals were asked to listen to sentences which related either to closed or open hand actions (interspersed with neutral, control sentences) and, upon understanding the sentence, required to press a button using either a closed or open hand (Ibáñez et al., 2013; see also Cardona et al., 2013 for explanation of the paradigm). The ACE is defined as a "…longer reaction time (RT) in the action-sentence incompatible conditions than in the compatible conditions", reflecting the link between motor activity and language (Ibáñez et al., 2013, p.968). Whilst the control participants in Ibáñez et al.'s (2013) study did indeed show such an effect – providing evidence *for* a role of motor processes in lexical-semantic processing – it was notably absent in individuals with PD, suggesting that, as a result of the network alteration caused by PD pathology, they were not able to utilise motor information during language processing.

A similar difference in the influence of compatibility between individuals with PD and control participants was reported by Buccino et al. (2018), in a task looking at graspable images. This go/no-go paradigm was somewhat similar in that individuals were required to provide a motor response (a button press) when the image they saw in front of them showed a real object, or the word they saw was a real word (Buccino et al., 2018). The images/words varied in their 'graspability' – i.e., whether the object was graspable or not graspable. The authors purport that the finding that control participants responded significantly more slowly to both words and pictures depicting graspable objects was reflective of the cost incurred through the motor system being recruited both to understand the word/object and to carry out the necessary response (Buccino et al., 2018). Conversely, the lack of any such effect in the PD group, combined with reduced overall accuracy, may suggest a reduced ability to utilise motor information in the processing of graspable objects in the group (Buccino et al., 2018). It is interesting too that, whilst controls produced a higher number of errors in the graspable condition and in response to photos, neither graspability nor stimulus type were shown to have a significant effect on error rate in the PD group.

Whilst both studies reported differences in the utilisation and influence of motor information between the groups, it is notable that the effect in the two tasks was opposed. Specifically, in Ibáñez et al.'s (2013) paradigm, motor compatibility facilitated processing (as indicated through faster responses) whilst within Buccino et al.'s (2013) paradigm the opposite effect was seen. This supports the idea that the influence of motor processes is not fixed but varies across the course of language processing, moving from early interference to facilitation in the later stages (see Buccino et al. for further discussion).

Somewhat in accord with Buccino et al.'s (2018) findings, Roberts et al. (2017), when investigating the specificity of verb processing impairment in PD according to whether the individuals' motoric impairment primarily affected their upper or lower limbs, found that individuals with upper limb impairment showed greater response latencies to upper as opposed to lower limb action verbs. This effect was not however seen in individuals with lower limb impairments, who showed similar response latencies for both verb types (Roberts et al., 2017). The authors discuss this finding in relation to theories which propose that the conceptual representations of upper limb actions are somewhat more firmly embodied, as shown through the larger size of the sensory-motor cortex associated with the upper limbs (Roberts et al., 2017, referring to García and Ibáñez, 2016, p. 54). Thus, as the authors go on to discuss, if we assume that the task required a relatively shallow level of semantic processing, it may be that an effect was not seen in the lower limb group because the conceptual representation of lower limb verbs are less reliant on sensory-motor information, meaning that successful processing was achievable even in the presence of reduced motor activation. The same could not be said for the upper limb verbs, whose conceptual representation is more reliant on sensory motor information and thus vulnerable to upper limb motor network impairment (Roberts et al., 2017).

The specificity of this finding is interesting to consider too in context of the broader finding from this same study. When collapsed across verb type (i.e., upper and lower limb verbs) and PD participants, there was no significant difference in general action verb processing between individuals with PD and controls (Roberts et al., 2017). In other words, whilst when looked at according to limb impairment, individuals with upper limb impairments showed a selective impairment in upper limb verb processing, this very specific effect was lost when both verb and participant type were collapsed into one group. Despite at first appearing so, this finding is not necessarily in conflict with that of Bocanegra et al. (2017) reported earlier. In Bocanegra et al.'s (2017) study, whilst a general verb difference did appear, this was traced back specifically to an alteration in the production of high action verbs. It is perfectly possible that the verbs used in Roberts et al.'s (2017) study could have been, on average, lower in action than those utilised in Bocanegra et al.'s (2017) study, meaning that no such general processing impairment appeared.

Collectively, these findings would indicate a specificity of verb impairment in PD, whether that be along the lines of limb impairment or motor content. Further it would seem that, whilst an alteration in high action processing may be strong enough to drive the appearance of a verb impairment at a general level (i.e., when collapsed across both high and low action verbs) the same cannot be said for upper limb verbs. Findings from both studies could be taken to support the notion that action verb processing is affected by PD pathology as a direct result of the degradation of motor networks. What they perhaps most importantly highlight however is that the breadth of this *sui generis* impairment appears to be limited and specific. This, in turn, presents questions as to what might be underpinning the general verb deficit which has been observed in other studies, within which the degree of action associated with the verb, or the limb required, has not been manipulated (e.g., Cotelli et al., 2007; Rodríguez-Ferreiro et al., 2009). It could simply be the case that the level of action of the verbs utilised within those studies (e.g., Cotelli et al., 2007; Rodríguez-Ferreiro et al., 2009) were high enough action to elicit an effect. It could as equally be the case however that the general verb – as compared with noun – deficit seen in Cotelli et al.'s, (2007) and Rodríguez-Ferreiro et al's. (2009) studies was underpinned by other processes, beyond semantic differences between the word classes. And, more broadly, that whether an effect is seen or not reflects a complex interplay of semantic and other factors, including the characteristics of the group of individuals with PD.

Before leaving this section, consideration will be paid to findings which could present a specific challenge to the motor-language coupling hypothesis, and whether the evidence considered thus far is able to counter them. The first relates to the lack, as demonstrated within a number of studies (e.g. Bocanegra et al., 2017; Péran et al., 2003; Signorini & Volpato, 2006) of a significant correlation between individuals' verb production ability and their Unified Parkinson's Disease Rating Scale (UPDRS) score. If, as proposed, the verb processing impairment in PD is related to the degradation of motor networks upon which semantic representations are also reliant, one might expect a correlation to be seen. However, as Péran et al. (2003) discuss, the UPDRS is a *general* measure of movement impairment and, bearing in mind the specific nature of the verb deficit which appears attributable to motor network impairment, it is perhaps not surprising that a significant correlation is not seen.

The indication that word processing deficits in PD become less specific – i.e., extend to lower motion verbs and nouns – as a consequence of broader cognitive impairment (Bocanegra et al., 2017) may also explain the lack of an association. Although there is not a straightforward relationship between the progression of physical and cognitive symptoms, if it were to be assumed that advanced physical symptoms were accompanied by advanced cognitive alteration in at least a subset of individuals, greater UPDRS scores may – somewhat counterintuitively – be expected to be accompanied by broader language alteration (i.e., an alteration in both noun and verb processing), due to the presence of broader cognitive alteration.

It is interesting too to consider here recent work by Cousins, Ash, and Grossman (2018) looking at verb production in individuals with PD and amyotrophic lateral sclerosis (ALS), in a discourse context. Findings from the study indicated no correlation between disease duration and the production of ‘body’ verbs in PD. Such an association was however seen in individuals with amyotrophic lateral sclerosis (ALS), with disease duration associated with the use of fewer ‘agent’ verbs (i.e., within which the person is doing the action) and a greater number of ‘theme’ body verbs (Cousins et al., 2018). Though this point is somewhat peripheral to the overall argument, the difference does suggest that the relationship between verb production and movement disorder in PD might be less straightforward than in other ‘motor’ conditions, potentially reflective of the multi-system nature of the condition (although it is fully acknowledged that cognitive changes can also accompany ALS; see for example Pettit et al., 2013; Phukan, Pender, & Hardiman, 2007). The evidence may therefore suggest a ‘non-linear’ pattern of cognitive decline in PD (Aarsland, Muniz, et al., 2011). Further comparison, ideally through a longitudinal design, between performance levels in different motor conditions could be elucidating.

Of additional relevance is the finding that, whilst there was no difference in individuals with low and high motor impairment in the production of body verbs, there was a difference between the groups in terms of the number of cognitive (i.e., abstract) verbs which were produced. Individuals with high motor impairment produced fewer cognitive verbs and, by extension, a higher proportion of body verbs (Cousins et al., 2018). This finding again appears to directly contradict predictions which would be made if the semantic hypothesis were to be correct. Although, it does appear more explainable by a hypothesis which assumes altered motor networks to underpin only a part of the verb deficit seen in PD. There is evidence to suggest that the processing of abstract verbs is more reliant on executive functioning systems (executive control). This is a reflection of the fact that such concepts are generally less tangible and thus able to appear in a greater variety of contexts, leading to a greater reliance on control processes to ensure that the correct interpretation is selected and competing alternatives inhibited (Alyahya, Halai, Conroy, & Lambon Ralph, 2018; Cousins, Ash, Irwin, & Grossman, 2017).

Whilst not statistically significant, a trend towards an association between the number of cognitive verbs used and scores on the general cognitive screen (MMSE; Folstein et al., 1975) utilised within Cousins et al.'s (2018) study was evident. This finding adds some support to the idea that subtle, subthreshold cognitive alteration may be contributing to the observed reduction in abstract verbs used (Cousins et al., 2018; note, however, no individual in the study had an MMSE score below 25). Thus, to further the hypothesis linked to Bocanegra et al.'s (2017) findings, it may actually be that when a certain cognitive threshold is reached not only does an extension of the lexical deficit appear but the expected verb deficit in effect flips, with abstract verbs actually becoming more difficult, due to increased cognitive demands. This suggestion only really holds here if it can be shown that individuals with higher motor impairment also had greater cognitive alteration – a comparison which is not available. The potential effect of task also needs to be considered, here. Fairly unusually for a study looking at verb production in PD, a discourse paradigm was employed, within which individuals were asked to describe the scene taking place in the *Cookie Theft Picture*. We might expect this paradigm to place greater cognitive demands than a semantic judgement task for example, thus subtle effects of altered cognition might be seen here that would not be evident in other tasks.

A number of other studies investigating ‘action’ versus ‘abstract’ verb processing in PD have utilised semantic similarity judgement tasks, within which individuals are asked to indicate which of two words is most closely associated to a target (Fernandino et al., 2013; Kemmerer, Miller, MacPherson, Huber, & Tranel, 2013; York et al., 2014). The first published of these, the work by Fernandino et al. (2013), found a significant difference in response time within the PD group, with action words responded to more slowly than abstract words; a pattern which was not seen in the control group nor, to a degree which reached significance, in the additionally included lexical decision task. This finding was not however replicated in either of the proceeding studies (Kemmerer et al., 2013; York et al., 2014), with no difference in accuracy between individuals and controls appearing in either verb category, in either study. In the former study (Kemmerer et al., 2013), within which reaction times were also measured, responses made by individuals with PD were found to be slower across the board, with no significant influence of verb type and/or dopaminergic status evident.

What may underpin the differences in findings observed between these studies is interesting to consider, however may at least in part reflect differences in the way in which the results were analysed, making them difficult to directly compare (a point Kemmerer et al., 2013, themselves refer to). Notably, Fernandino et al. (2013)

primarily conducted within-subjects comparisons (i.e., compared mean RT and accuracy scores in the abstract versus action condition within each group) with comparison between individuals with PD and controls limited to the 'net' verb score calculated through subtracting performance in the abstract condition from the action condition. York et al. (2014), in contrast, included comparison of performance in each verb condition between individuals with PD and controls, whilst Kemmerer et al. (2013) conducted mixed factorial analyses of variance (ANOVAs). Furthermore, because of additional interest within the Kemmerer et al. (2013) study was the impact of different action verb types (e.g., running, hitting, cutting etc.), the verbs utilised may have been broader – both in terms of the limb used to conduct them and the level of action associated with them – than those used by Fernandino et al. (2013) and thus potentially 'hidden' a more specific deficit.

Indeed, it was interesting to observe that, within the additional analysis conducted, Kemmerer et al. (2013) found that accuracy in judging the semantic relatedness of both 'cutting' and 'psych' (non-action) verbs negatively correlated with disease duration in the PD group off dopamine (Kemmerer et al., 2013). Given that cutting verbs are upper limb verbs, this finding appears to be somewhat in accord with the findings of Roberts et al. (2017), although it should be stressed that the participants in Kemmerer et al.'s (2013) study were not divided according to limb impairment. Nonetheless, the finding indicates that upper limb verbs may be more vulnerable in PD, with altered processing increasing as the condition progresses, regardless of specific limb impairment. The fact that this link only appeared in individuals who were off dopamine might also suggest that dopaminergic therapy is successful in remediating the effect.

York et al. (2014) observed no difference between accuracy in the processing of abstract or action verbs, or in the processing of abstract or concrete nouns in individuals with PD, as compared with controls. Furthermore, both individuals with PD and controls showed greater accuracy in the processing of action, as compared with abstract verbs (a pattern also reported by Roberts et al., 2017, in relation to response latency). As previously touched upon, it has been suggested that the processing of abstract verbs is more demanding on cognitive resources (see also Bastiaanse, Wieling, & Wolthuis, 2016, for further discussion regarding the processing of concrete versus abstract words). Also, given that some of the individuals with PD in this study had MCI or dementia (York et al., 2014), it is perhaps surprising that there was not an observable deficit of *abstract* verb processing in the PD group, as compared with controls. If motor network damage translates to a relatively mild verb impairment, we might expect to see a point at which any verb deficit linked to cognitive alteration is more prevalent than that linked to motor impairment. This is considering findings from Bocanegra et al. (2017), regarding our knowledge of the cognitive impairment which can accompany PD and the indication that abstract verbs may place heavier cognitive demands.

It was interesting, too, that performance in York et al.'s (2014) study in response *both* to action and abstract verbs was correlated[7] with executive functioning – again a finding which would not necessarily have been predicted. It must be noted however that executive functioning was measured through verbal fluency tasks, thus there is the possibility that the lexical element of this task influenced the associations seen.

In summary, this section has considered the evidence available which, through examining the processing of different types of verbs, is able to offer insight into the potential root of the verb deficit observed in PD, without the confound of

[7] Note, the direction of this correlation is not provided.

grammatical word class. The findings presented here, whilst relatively limited, do present some support for the hypothesis that damaged motor networks in PD, through the contribution of these same networks to conceptual representations, is underpinning an alteration in lexical semantic processing in PD. And, by extension, add to the argument that the verb deficit observed is a reflection of the 'action' meaning associated with the verb, as opposed to any 'grammatical' differences which distinguish verbs from nouns. However – and it is quite a sizeable caveat – the evidence does not point to a general 'action' (as opposed to verb) word deficit in individuals with PD without cognitive impairment; rather the impairment attributable to motor network impairment appears to be limited and specific. Furthermore, these specific impairments tend to appear only when 'action' verbs are being compared according to type (i.e., high versus low action). Whilst one study found evidence to the reverse, generally the currently available evidence does not support a significant difference between abstract and action verb processing in PD.

This leaves us with a question as to what may be underpinning the differences in performance according to word class in PD, as have been reported within a number of studies. There is certainly evidence to suggest that cognitive alteration, particularly an impairment in executive control required for successful retrieval (selection processes), may also be involved – with potentially greater influence, at least once a certain threshold has been reached. Whilst informative, the findings also do not enable us to rule out any potential difference in processing according to grammatical factors separating the word classes – such as, for example, the lexical-syntactic information accompanying verbs. Discussion will now move to consider in greater depth the influence of selection demands and executive control on verb processing in PD, before finally moving on to a consideration of what is known about the influence of grammatical differences between the word classes in PD, and whether any useful insights can be gleaned from aphasia.

1.2.3.3 Verb processing in PD: the influence of selection and control mechanisms

Relatively central to the debate regarding language impairment in PD is whether any alteration observed is linguistic in nature, or reflects alteration to other cognitive functions which play a supporting but necessary role in language processing (Bastiaanse & Leenders, 2009; Colman & Bastiaanse, 2011). As part of this debate, the patterns of impairment seen in PD have been compared with those seen in Broca's aphasia. It is notable that some authors have, from this comparison, concluded that the language impairments seen in the two populations are qualitatively different, with Broca's aphasia reflecting a linguistic impairment and language alteration in PD reflecting an underlying alteration in supporting cognitive processes (Bastiaanse & Leenders, 2009). Whilst the differences in processing observed between the groups may indeed be elucidating, building this comparison on whether the impairment is 'linguistic' or 'cognitive' in nature may be somewhat misleading.

The language difficulties seen in aphasia have historically and are still most typically postulated to reflect the loss of language rules and representations (McNeil, Hula, & Sung, 2011) – separating aphasia from those communication disorders which arise as a result of broader cognitive impairment. There is increasing recognition however of the cognitive alterations which can coincide with and contribute to the language difficulties seen in aphasia (Salis, Kelly, & Code, 2015). Some authors have gone so far as to suggest that aphasia is a disorder of *processing,* such that linguistic representations and rules are actually largely intact - what is damaged is the ability to build these representations, reflective of damage to the broader cognitive architecture required for language processing (McNeil et al., 2011; see also Thompson et al., 2018, for discussion regarding the observed overlap in performance between individuals with semantic aphasia and dysexecutive syndrome as a result of head injury). Under such a view, the previously reported differences in language impairment in individuals with Broca's aphasia as compared with individuals with PD might in fact *both* be underpinned by an alteration in the broader cognitive architecture necessary for successful language processing – but a different part of the architecture. Thus, considering the presentation of language impairment according to whether it is 'linguistic' or 'cognitive' in nature may be simplifying the argument to a degree which risks masking our understanding of the impairment both at a behavioural level and in relation to the corresponding neural architecture. What instead might be more appropriate to consider therefore is whether any cognitive involvement appears central to language processing, or whether its influence is arising as a result of the task, making its influence somewhat more peripheral.

For example, there is increasing acknowledgement of the important and necessary role of cognitive control (alternatively termed executive control) in language processing (Ye & Zhou, 2009). These control processes, whether they in themselves are domain general or domain specific, could be described as 'core' to language processing, if we consider them to be central to it. Thus, we might expect an alteration in language production which appears attributable to alteration in the ability to inhibit competing alternatives, for example, to present irrespective of task. That is in contrast, however, to situations whereby language alteration presents and again is thought to reflect an alteration in supporting cognitive processes, but this time more peripherally – such that it is arising as a direct result of the design or cognitive demands of the task, for example. A good example of this comes from two studies both looking at the production of past tense verbs in PD (Colman et al., 2009 and Longworth, Keenan, Barker, Marslen-Wilson, & Tyler, 2005). In the latter, the deficit observed was linked to the role of the striatum in selection and the inhibition of competing alternatives. In the former however - at the acknowledgement of the authors themselves – the impairment in tense production was again linked to executive impairment (an alteration in set shifting). However, this time it appeared to arise as a consequence of the task design and materials. This distinction is one which appears to have been overlooked within previous discussions regarding the cognitive underpinnings of language impairment in PD (Bastiaanse & Leenders, 2009). Yet, it could be of both theoretical and practical importance.

It was mentioned in the introduction to this section that some variability has been seen in language performance in PD, across the literature. When considering the semantic hypothesis, consideration was given to the proposal that, depending on the depth of semantic processing required by the task, individuals with PD may show no impairment, even in the presence of underlying damage to the conceptual representation of actions. In a similar vein, if, as is about to be discussed in more depth, the verb processing impairment in PD is linked to an alteration in cognitive control, one might expect differences in the severity of impairment to be seen dependent on the cognitive demands of the task. This is of important functional relevance as, if it is understood under which circumstances processing impairment is most likely to present, alterations to the external environment can be made to compensate for it. It is also important from a theoretical perspective, given the insights such knowledge may provide regarding why we are seeing certain impairments in PD and whether they are likely to be seen in more naturalistic settings.

As touched upon in the previous section during consideration of the findings of Cousins et al. (2018), an alternative – but not incompatible – hypothesis regarding the root of the verb alteration seen in PD is that it is linked to an alteration in executive control mechanisms. In the case of Cousins et al.'s (2018) findings, this discussion centred on how differences in the cognitive control demands of abstract and concrete concepts (which could in turn translate to action vs abstract verbs) may explain why individuals with high motor impairment were shown to use a lower number of abstract but higher number of body verbs. As will be discussed throughout this section, the hypothesis, too, may explain differences that appear between nouns and verbs, as a word class.

As discussed in Section 1.2 and 1.2.1, whilst originally considered primarily in relation to motor control, the complexity of the basal ganglia is becoming increasingly realised, with current conceptualisations acknowledging the involvement of the component subcortical structures in a number of circuits – including that subserving cognitive and executive functions, via circuits connecting the striatum and the frontal cortex (Alexander & Crutcher, 1990; DeLong & Wichmann, 2010; Lanciego, Luquin, & Obeso, 2012 - see also Elliott, 2003). Executive dysfunction is commonly associated with PD, assumed to reflect damage to the aforementioned corticostriatal circuitry (Broeders et al., 2013). In relation to lexical and semantic processing, it is proposed that executive control processes are recruited in the presence of increased competition and in instances within which a prepotent response needs to be overridden in favour of a more weakly activated representation or interpretation (Thompson-Schill, Bedny, & Goldberg, 2005; Ye & Zhou, 2009). There is increasing evidence linking these regulatory control processes with activation in the left ventrolateral prefrontal cortex (VLPFC)/left inferior frontal gyrus (IFG; Thompson-Schill et al., 2005 - see also Ye & Zhou, 2009, for discussion). Also implicated are basal ganglia nuclei, with imaging studies highlighting activation in both regions (i.e., the left IFG and the basal ganglia) connected via functional pathway (Cousins & Grossman, 2017; see also Gabrieli, Poldrack, & Desmond, 1998, and Silveri et al., 2018 for discussion).

Interestingly, this same area drew attention in the literature examining the differences in neural signatures between nouns and verbs, following findings indicating activation in that region during verb as compared with noun processing (see Vigliocco et al., 2011 for a review). It was originally considered that this area may be specific to the processing of verbs; supporting the notion that neural activation patterns varied as a function of word class. However subsequent work, such as that by Siri et al. (2008), would suggest that involvement of the IFG during verb processing is not a reflection of word class *per se*, but is a reflection of lexical selection demands, which are typically greater in verbs as compared with nouns. The aforementioned authors drew this conclusion through implementing a paradigm within which the semantic confound was controlled and the conditions manipulated such that nouns effectively placed greater lexical processing demands than verbs. This, in turn, was shown to lead to greater activation in the IFG for nouns than for verbs (Siri et al., 2008). Ignoring for a moment what is known about the selective verb deficit in PD, if we were to assume – as has been suggested here – that verbs place greater processing demands than nouns, and given what is known about the vulnerability of executive processes in PD, one could go as far as to predict a deficit in language processing, in instances within which cognitive control processes are required. Indeed, there is a body of evidence to suggest that the verb deficit in PD may be reflective of altered cognitive control mechanisms during language processing.

Adopting a somewhat similar approach to Siri et al. (2008), Silveri et al. (2018) presented individuals with PD and matched controls with a word and asked them to convert that word into a word of an alternative word class. For example, if an individual was given the verb ‘to observe’ and asked to produce a noun, the target would be ‘observation’. The number of potential responses varied depending on the word class of the required response. For example, in the condition within which individuals were given a noun and asked to turn that noun into a verb, only one potential option was available. In contrast, if individuals were given a verb and asked to turn that verb into a noun, multiple potential options were available. Thus, within this paradigm, when a verb was required there was only one word form to choose from, whereas when a noun was required there were multiple word forms to choose from. The paradigm therefore created a situation opposite to that seen within typical processing, within which verbs have a greater number of potential word forms than nouns (Silveri et al., 2018). It should be stressed that this study was not concerned with the semantic meaning of the words, purely with lexical word form. As such, some of the potential targets – whilst being derived from the input word – did vary slightly in meaning from the input.

Under these conditions, individuals with PD only showed impaired performance, as compared with controls, when required to produce a noun from a verb. In other words, in the condition within which the highest number of potential word forms were present (Silveri et al., 2018). This finding would indicate that – as the authors discuss – an increase in the number of lexical word-form options available has a noticeable impact on production in PD, due to the greater selection demands arising from increased competition (Silveri et al., 2018). Further, given that, under typical circumstances, a greater number of word forms are associated with verbs as compared with nouns, increased selection demands – and, importantly, the executive control demands that accompany that – may at least in part explain the verb production deficit observed in PD (Silveri et al., 2018).

An effect of selection demands has been seen too at a lexical-semantic level of processing. Crescentini, Mondolo, et al. (2008) applied a semantic association task to assess the influence of the strength of association between a stimulus (the cue) and the potential target, on production. Across various association strength conditions, individuals were given a noun and asked to produce either a related verb or a related noun, as quickly as they could. Results indicated that whilst performance on noun production was comparable to controls, individuals with PD were significantly impaired in the production of verbs; a finding which presented in all association conditions (Crescentini, Mondolo, et al., 2008). The authors discuss these findings both in relation to the strength of association between the cue and the target, and in relation to the number of irrelevant competitors which arise due to the nature of the task and the default structure of the semantic system (Crescentini, Mondolo, et al., 2008). It is proposed by the authors that, in the weak association condition – i.e., when individuals are asked to produce a verb of low association in response to a noun – the recruitment of executive control processes is required in order to bias activation away from information which is more strongly associated but irrelevant, and towards the information which is less strongly associated but relevant. In the high association condition, the influence of the default nature of the semantic system comes more sharply into focus; the authors propose that, because nouns are more associated with other nouns, even in the high association condition, a number of irrelevant nouns are likely to also be activated in response to the ‘cue’ verb, and be more strongly activated than the relevant verb. Thus, even in the high association condition, successful utilisation of executive control processes is required to steer away from the more highly activated, prepotent response to the relevant information (Crescentini, Mondolo, et al., 2008). The authors conclude that the selective verb deficit observed in PD appears to be resulting from a reduced ability to successfully implement the executive control processes which are necessary when automatic retrieval cannot take place. That is, when top down control is required for successful retrieval (Crescentini et al., 2008 - see also Ketteler et al., 2014).

It is interesting too that, given the significant correlation between performance in the verb task and measures of executive function, the authors allude to the fact that the executive control deficit associated with altered language processing in PD may be a ‘general’ one. This supports the idea that the role of the basal ganglia in language processing in PD is not specific to language per se, but reflective of the general role of the basal ganglia in regulatory, executive control, when selection and inhibition of competing alternatives is required (Crescentini, Mondolo, et al., 2008). It is interesting to note that the same association between verb and executive processing was not however seen by Bocanegra et al. (2015), who found executive functioning to predict neither verb naming accuracy, or performance within an action-semantics task. An association was however seen between executive functioning and object semantics; a relationship limited in Crescentini, Mondolo, et al.'s (2008) study to performance within the Trail Making B and noun task. The difference in findings seen here could represent differences in the verb processing tasks utilised (i.e., a semantic association task vs a naming task) and/or the measure(s) of executive functioning taken.

Findings from another word association task (Castner et al., 2008), this time additionally considering the influence of subthalamic nucleus (STN) stimulation on performance, provides further insight. As compared with controls, performance in the verb-verb condition (i.e., the production of a verb in response to another verb) was significantly impaired in individuals with PD, in both the ‘on’ and ‘off’ stimulation conditions. In contrast, the performance of individuals with PD in the noun-verb condition was significantly impaired (as compared with controls) in the ‘off’ condition but not the on condition; suggesting that STN stimulation improved individuals with PD’s ability to produce a verb from a given noun. STN stimulation appeared to have the reverse effect however when individuals were asked to produce a noun from another noun, with individuals with PD making significantly more errors than controls in the ‘on’ but not the ‘off’ condition (Castner et al., 2008). Thus, under the STN ‘on’ condition, a significant difference in both verb and noun production was evident in individuals with PD; in effect eradicating the selective verb deficit seen in the ‘off’ STN condition (Castner et al., 2008). What is particularly interesting, too, is the finding that whilst errors made by the PD group in the verb production condition (i.e., noun-verb and verb-verb) correlated significantly with selection constraint in the ‘on’ STN condition, there was no significant correlation between errors in any condition and selection constraint in the ‘off’ STN condition.

The authors discuss their findings in relation to previous work positing STN stimulation to be associated with reduced verbal fluency; reflecting in part reduced cerebral blood flow to the left IFG (Castner et al., 2008). Thus, the finding that verb errors were only significantly associated with selection constraint in the ‘on’ stimulation condition adds some support to the role of the IFG in cognitive control during language processing. However, it does not offer any insight into *why* noun difficulties presented in the ‘on’ but not ‘off’ stimulation condition, or why individuals with PD showed no difficulty producing a verb related to a given noun in the ‘on’ stimulation condition, but did in the ‘off’ stimulation condition. It could be the case that – if we assume that the retrieval of a related noun from a given noun is achievable through automatic semantic activation – STN stimulation also affects automatic semantic processing, leading to a deficit in noun as well as verb production. It is interesting, too, that difficulties in the production of a verb from a given verb presented in both STN stimulation conditions, but difficulties with verb production from a given noun only appeared in the ‘off’ condition.

The authors conclude that, given the lack of a significant relationship between production errors and selection constraints in the ‘off’ stimulation condition, that the verb deficit seen in individuals with PD is a reflection of a difficulty in producing the grammatical word class of ‘verbs’, not an impairment in lexical selection (Castner et al., 2008). However, their conclusion also purports the involvement of the IFG in selection of the target from competing alternatives (Castner et al., 2008). Thus, one could conclude by extension that – given that the production of a verb from a given verb was impaired in PD in both the ‘on’ and ‘off’ stimulation conditions – that the factors underpinning the verb production deficit seen are different in the two conditions. By further extension, this could imply that what is underpinning the verb difficulties seen in PD might not be the same in all conditions, or at all points within disease progression – as touched upon in the previous section.

The potential influence of the semantic meaning of the words in question appears to have been looked at only partially in Castner et al.'s (2008) study. The authors looked at the effect of the semantic attributes of the probe and found no significant effect of them. However, they did not look at the semantic content of the expected responses, for example whether responses to certain probes were expected to be ‘higher action’ than others. Thus, it is difficult to tell whether or not the semantic content of the target responses had any impact in the ‘off’ stimulation condition, and whether or not this might explain the verb deficit seen. Or, as the authors conclude, it could be a reflection of the grammatical differences between the word classes. Finally, the fact that STN stimulation appeared to improve word production in some instances (i.e., in the production of verbs from nouns) but worsen it in others (i.e., the production of nouns from nouns) further suggests a complex relationship between word class, STN stimulation (via its influence on the IFG, and potentially other regions) and automatic and controlled semantic activation. As discussed by Silveri et al. (2012), in light of their finding which suggested that STN improved verb naming in response to picture stimuli, this could also potentially be influenced by task demand, and the depth of processing required within the task, or different conditions within the same task.

It is important to bear in mind, too, that the global cognitive status of the individuals with PD in Castner et al.'s (2008) study was not indicated, making it impossible to establish any influence of broader cognitive decline on the results seen. Studies looking at verbal fluency – particularly those looking at action as compared with semantic and phonological fluency - provide some interesting findings in this regard. Piatt et al. (1999) reported no significant differences in lexical, semantic or action fluency in individuals with PD without dementia. However they saw a significant decline in performance in all three tasks in those diagnosed with PD dementia, with action fluency the most affected. This was as compared with the other groups, i.e., individuals with PD but without dementia, and controls. Interestingly, whilst there was a trend seen towards a significant association between individuals with PD's dementia scores on the dementia rating scale (DRS) and their lexical and semantic fluency scores, there was no relationship between action fluency and this same measure of general cognitive performance. Thus – whilst a difference in verbal fluency across the board only presented in individuals with dementia – as Piatt et al. (1999) conclude, findings would indicate that alteration in performance across the three different measures may not be associated with the same underlying processing.

Relatedly, whilst Salmazo-Silva et al. (2017) found no significant difference in either noun (semantic) or verb (action) fluency between individuals with PD (without dementia) and controls, a difference in correlation pattern between the two fluency conditions was evident. Whilst noun (semantic) fluency correlated significantly with scores on the MMSE, scores in the action fluency condition correlated significantly with disease progression (as measured through Hoehn and Yahr scores). Again, this indicates that the processes associated with performance in action and semantic fluency may be different (Salmazo-Silva et al., 2017). The authors – as, with Piatt et al. (1999) - discuss this finding in relation to executive dysfunction, and the greater demands placed on executive function processes (known to be vulnerable in PD) by action fluency tasks. The fact that no alteration in action fluency was seen in the individuals in Salmazo-Silva et al.'s (2017) study could therefore be purported to reflect the fact that the disease severity (and by extension, associated executive impairment, aside from any more general cognitive decline) of the group was not great enough for any effect to be evident. Or, bearing in mind Piatt et al.'s (1999) finding, it might indicate an interesting relationship between general cognitive decline and executive dysfunction; such that the effect of the latter only has a functional effect on action fluency in the presence of broader, more global cognitive decline.

This second hypothesis seems somewhat unlikely, however, given findings from other studies which have indicated a selective action fluency deficit in PD, in the absence of broader cognitive decline (e.g., Signorini & Volpato, 2006). This study by Signorini and Volpato (2006) is particularly interesting as it assessed individuals at ‘baseline’ and again at four, 6-monthly intervals. A selective action fluency deficit was observed both at baseline and follow up in the PD group – but, at neither point did performance in the action fluency task correlate significantly with scores in the

MMSE, UPDRS or on the Hoehn and Yahr scale (Signorini & Volpato, 2006). Again, the authors discussed this in relation to executive dysfunction and the greater demands placed through the action fluency task, within which individuals are having to select from a whole word class, as compared with the semantic and phonemic tasks which are more constrained. It is interesting, too, that in this group of individuals who showed an impairment of action but not semantic fluency, that there was no significant decline in general cognitive ability (as measured through the MMSE and the Milan Overall Dementia Assessment), between the time points. This, in turn, is interesting to consider in relation to the work of Williams-Gray et al. (2013) referred to in Section 1.2.1.

A further interesting finding from Signorini and Volpato's (2006) study is that neither object or action naming were found to be impaired in PD, indicating a dissociation between performance in action naming and action fluency. The authors discuss this in relation to the findings pointing way from the presence of a lexical deficit in PD (i.e., a specific deficit of processing verbs, as a grammatical word class) and instead to it being a subtle executive dysfunction (Signorini & Volpato, 2006). Somewhat relatedly, in their work looking at verbal fluency in individuals with PD, Alzheimer's Disease (AD) and controls, McDowd et al. (2011) – whilst again reporting a relative deficit in action fluency in individuals with PD – found that, across the board, verbal ability was not a significant predictor of performance in the verbal fluency tasks. Indeed it was processing speed that was the strongest predictor of performance, with the authors reporting an even more greatly pronounced association between processing speed and action fluency in the PD group (McDowd et al., 2011).

Against this backdrop, it is interesting to consider the findings of Bocanegra et al. (2015), which appear in direct contradiction to those reported by Signorini and Volpato (2006). Specifically, Bocanegra et al. (2015), observed a verb naming deficit in individuals with PD without MCI, which did not appear to be predicted by executive functioning performance. In neither this, nor in Signorini and Volpato's (2006) work did the authors specify whether the actions being named were ‘high’ or ‘low’ action. Thus, it does not seem that any difference in these findings can be traced back to observable differences in the ‘motor’ demands of the action verbs under consideration. Sample sizes were comparable between the studies, and there was little difference between average Hoehn and Yahr and UPDRS scores. Average years of schooling in Bocanegra et al.'s (2015) study was over four years greater than in Signorini and Volpato's (2006) study, presenting the possibility that educational attainment acts as a protective factor for neurotypical individuals. This hypothesis is not supported by the data however, which shows both individuals with PD and controls scoring pretty much at ceiling within Signorini and Volpato's (2006) study. The difference could reflect subtle differences in the level of action of the stimuli used, or differences in the number of tasks conducted as part of the study, and levels of cognitive fatigue. Either way, this inconsistency between studies is interesting to consider.

There are subtle differences in findings, too, between the same study by Bocanegra et al. (2015) and findings reported by Salmazo-Silva et al. (2017). Both authors found that performance within semantic association tasks not involving lexical information (i.e., the Pyramid and Palm Trees test, the Camels and Cactus test and the Kissing and Dancing Test) was impaired in PD, for both objects and actions. And both, too, found a relationship between performance in the object semantic association task and cognitive performance. What is interesting however is that whilst Salmazo-Silva et al. (2017) report a correlation between scores on the MMSE (Folstein et al., 1975) and object semantic association, Bocanegra et al. (2015) indicate a somewhat more specific association between performance on the executive functioning task and object semantics – and furthermore, show the same association in individuals with and without MCI. Thus, it seems that executive functioning ability might be contributing to object semantics, both in the presence and absence of more global cognitive decline. The fact that, in Salmazo-Silva et al.'s (2017) study, object semantics correlated significantly with general cognitive performance, could simply reflect differences in the nature of the analyses – however this comparison does raise a potentially important distinction between executive dysfunction, global cognitive decline and alterations in semantic processing in PD. Furthermore, the fact that, in Salmazo-Silva et al.'s (2017) study, an impairment in the object semantic association task presented in the absence of an alteration in noun naming – and that, unlike performance in the object semantic association task, performance in the noun naming task was not significantly correlated with scores on the MMSE – again highlights the influence of task, which may in turn be differentially associated with cognitive performance.

Before concluding this section, brief attention will be paid to the literature investigating semantic processing more broadly in PD; primarily through priming tasks. The research presented thus far would suggest that controlled semantic processing may be affected by PD and may be underpinning – either entirely or in part – the verb deficit seen. An alteration in controlled lexical-semantic processing, indicated to reflect an alteration in the ability to inhibit competing alternatives, has also been observed in studies looking at semantic processing more broadly; both within priming tasks (Angwin et al., 2005; Arnott, Chenery, Murdoch, Silburn, & Chenery, 2001; Arnott et al., 2011; Copland, Sefe, Ashley, Hudson, & Chenery, 2009) and word search tasks (Arnott et al., 2010). Importantly there is an indication, too, that automatic semantic activation may also be impaired in PD, reflecting a delayed time course of semantic activation and decay (Angwin et al., 2009, 2005;

Angwin, Chenery, Copland, Murdoch, & Silburn, 2007; Arnott et al., 2001) – and that this may be exacerbated when off dopaminergic medication (Angwin et al., 2007; Arnott et al., 2011). Furthermore, the influence of dopamine on semantic priming has been discussed in relation to altered signal-noise ratio, in effect altering the salience of relevant and irrelevant stimuli (Angwin et al., 2009, 2005).

In summary, this section has considered an alternative hypothesis to explain the observed verb deficit in PD; one which attributes the verb naming deficit in PD to an alteration in the recruitment of controlled cognitive processes during language processing. It proposes that, because there are more conceptual and word form 'options' for verbs as compared with nouns, a selective verb deficit appears.

Also under consideration has been differences in the relationship between executive functioning specifically, and broader cognitive decline more broadly, and language processing. Current findings would suggest a somewhat complicated relationship, which may be further intertwined with task demand. Perhaps partly as a consequence, questions also arise as to whether the verb alteration seen is always a reflection of the same underlying processing. This same theme was touched upon above in the section considering the semantic hypothesis of verb impairment in PD - and, given that the basal ganglia circuity is linked to both motor control and executive functioning, it seems perfectly plausible that the verb impairment seen is a complex mix of motor and executive, cognitive control elements (see Cousins et al., 2018, for further consideration of this point).

Not all authors have, however, linked the verb difficulty seen solely to selection constraint. Castner et al. (2008), for example, suggested that the verb deficit may reflect differences between nouns and verbs as a function of grammatical word class. Both in relation to PD and the verb/noun dissociation more broadly, it is not uncommon to see difference in the performance between nouns and verbs discussed in relation to the increased complexity of verbs. In other words, the fact that verbs are intrinsically more difficult. So far in this discussion we have considered differences between verb and noun production in PD in relation to an increased number of conceptual options or lexical word forms. Yet to be considered however are other aspects which also contribute to a verb's complexity; particularly the accompanying lexical-syntactic information.

1.2.3.4 Verb processing in PD: the influence of grammatical word class

So far, differences between the processing of nouns and verbs have been considered in relation to semantic differences, and differences in the executive control processes required for successful retrieval. There are, however, other differences between nouns and verbs which have been proposed to account for verbs being generally more 'difficult' to process than nouns. One such example is imageability. The fact that verbs are less imageable than nouns – making them harder to process – is often discussed with, in some quarters, authors going so far as to suggest that the difference in verb and noun processing seen in individuals with aphasia is attributable to differences in imageability (see Bastiaanse et al., 2016 for discussion). However – putting aside for a moment concerns about whether 'imageability', ratings are entirely comparable between nouns and verbs, and the uncertainty about what the construct of imageability actually is (see Mätzig et al., 2009, for disucssion) – research would suggest that whilst imageability influences the retrieval of both nouns and verbs, it cannot, alone, explain why verbs are more difficult than nouns (Bastiaanse et al., 2016).

Another reason proposed to explain the difference in noun and verb performance is one of word class, reflective of differences in the amount of information specified at the lexical level (see Bastiaanse et al., 2016; Caley, Whitworth, & Claessen, 2017, for discussion). Unlike nouns, research would suggest that verbs play a pivotal role in sentence production, through specifying argument structure and associated thematic role assignment (Bastiaanse et al., 2016; Caley et al., 2017). The effect of this lexical-syntactic information at a single word level, however, depends on the view taken of when such information becomes available. In lexicalist models, this lexical syntactic information forms part of the lemma and is assumed to always be available (Vigliocco et al., 2011). In other interpretations however, such information is considered to only become available (and thus be necessary) during sentence processing (Vigliocco, Vinson, & Siri, 2005 - see also Vigliocco et al., 2011, for review).

It is interesting that, in one of the reviews discussed earlier looking at the processing signature of nouns versus verbs (Vigliocco et al., 2011), the authors conclude – largely it seems based on findings of their earlier work (Vigliocco et al., 2005) that their findings do not support 'strong' lexicalist models, within which grammatical class information would always be made available during processing. However, upon drawing that conclusion, the authors appear to be overlooking the fairly sizeable body of evidence from the aphasia literature indicating an effect of a verb's grammatical complexity – as measured both through the number of syntactic arguments (e.g., Caley et al., 2017; Thompson, Lange, Schneider, & Shapiro, 1997) and the complexity of the associated structure of those arguments (Thompson, 2003) – in verb naming tasks.

The effect of word class in aphasia has been discussed both in relation to the greater amount of information associated with the verb lemma, and in relation to the demands of grammatical encoding (Bastiaanse et al., 2016). In their discussed model of language processing (based on that of Levelt, 1989, cited in Bastiaanse et al., 2016, p.2), Bastiaanse et al., (2016) discuss the role of the grammatical encoder which, it is purported, receives information both from the preverbal message and through the lexical syntactic information attached to the verb (at the lemma level). Grammatical encoding, they propose, takes place both at a sentence and a single word level, with single verb production being the simplest, minimal frame. Under such a model, grammatical encoding has the capacity to influence retrieval both at a single word and sentence level (Bastiaanse et al., 2016). And, indeed, the authors propose, from findings primarily from their own work, that it is grammatical encoding which is impaired in aphasia. The more information that needs to be encoded (either because of the number of arguments, or the structure and thematic mappings of those arguments) the more difficult the processing will become (Bastiaanse et al., 2016).

It is interesting too, however, to consider how the amount of lexical syntactic information – in terms of the number of featural and combinatorial syntactic nodes (Pickering & Branigan, 1998) – might influence successful retrieval. One might hypothesise, for example – given the findings from Section 1.2.3.3 considering altered cognitive control in PD – that verbs which have multiple possible sentence frames (for example, verbs which can take either one or two arguments) may be vulnerable in PD (whether that manifests as reduced accuracy, or increased formulation time) due to the increased number of options.

Interestingly, work by Rodríguez-Ferreiro, Andreu, and Sanz-Torrent (2014) found that, in neurotypical individuals, transitive verbs were processed more quickly than intransitive verbs. The authors discuss this finding not in terms of syntactic differences but differences in ‘semantic richness’. Specifically the fact that, because transitive verbs have richer semantic connections – presumably because they are associated with a variety of objects which can take the object slot – they have lower activation thresholds than verbs with sparser semantic connections (Rodríguez-

Ferreiro et al., 2014). A somewhat similar pattern was seen in a recent study looking at verb production in aphasia, with verbs which could take either an intransitive or transitive frame named more quickly than those which had to take a transitive frame (Malyutina & Zelenkova, 2020).

It is interesting to consider these findings, too – and the discussion of their origin in relation to the role of semantic richness – against the findings of Breedin, Saffran, and Schwartz (1998). In their study, the authors observed that a number of individuals with aphasia showed a tendency to retrieve ‘heavier’, more complex verbs – and substitute lighter verbs with more complex ones. They discussed this finding in relation to constraint – in this instance of the contexts within which the verb could occur. The authors propose that, because ‘heavier’ verbs are generally more specific in the ways in which they can be used and the context in which they can appear, their meaning is more constant. In contrast, light verbs (such as ‘go’, for example) can appear in a variety of contexts, which can subtlety influence their meaning. Thus, whilst heavy verbs might activate one meaning, light verbs might activate multiple; requiring successful application of selection processes (Breedin et al., 1998). In PD therefore, a different pattern might be expected. Rather than being facilitatory, increased semantic richness – depending on whether it specifies or creates more options – might in fact impact negatively upon retrieval.

A further interesting finding from Malyutina and Zelenkova's (2020) work touched upon earlier is the different effect of lexical-syntactic information seen at a single word and sentence level. At the sentence level, an increase in the number of arguments taken by the verb was shown to lead to a reduction in grammatical completeness, with sentences more likely to either be missing necessary arguments or contain extra ungrammatical arguments, or evidence incorrect word order. In contrast, the number of frames a verb could take – i.e., if the verb could take one or two arguments, or had to take two arguments – was not found to have a significant effect at a sentence level. It did, however, have a significant effect at a single word level, with naming latency found to be lower in verbs which could take two sentence frames as compared with those which could only take one. Interestingly, too, whilst unaccusative verbs were named less accurately than non-ergative, one argument verbs, there was no effect of unaccusative verbs at the sentence level – despite them often being considered to be more structurally complex.

These findings bring us back to questions regarding when lexical-syntactic information is accessed, and whether what could be perceived to be an effect of lexical-syntactic information may actually reflect semantic richness (that being said, the finding that unaccusative verbs – known for their structural, syntactic complexity – had an impact at the single word level, is important to bear in mind here). This is interesting to consider too in relation to findings from aphasia studies which would indicate that lexical syntactic information may be represented separately to lexical semantic information – given patterns seen in individuals with aphasia who have verb argument difficulties but appear able to access lexical-semantic information without difficulty (Caley et al., 2017; see also Webster & Whitworth, 2012 for discussion). This potential dissociation presents a number of testable hypotheses: if, for example, an individuals' sentence production alteration is linked to lexical-semantic alteration, one might expect improved sentence production in instances within which lexical-semantic retrieval demands have been reduced through provision of the verb. If, however, impairment is at the lexical-syntactic level, providing the verb might have no discernible effect on the accuracy of argument structure (see Webster, Franklin, & Howard, 2004 and Whitworth, Webster, & Howard, 2015 for discussion).

It is interesting that the observed specific verb deficit in PD has garnered noticeably different hypotheses and lines of enquiry than the observed noun/verb dissociation observed in individuals with aphasia. Whilst the lexical-syntactic information carried by verbs has been central to investigations in the aphasia literature, it has not featured in the PD literature exploring the same observed dissociation. Furthermore, conversely, whilst there is increasing interest in the aphasia literature regarding broader cognitive alterations in individuals with aphasia, the potential presence of differences in performance according to the 'action' associated with the verb has received little attention (although see Riccardi, Yourganov, Rorden, Fridriksson, & Desai, 2019 for consideration of abstract and action verb processing, post stroke). Both literatures might well benefit from looking to the other for means through which to expand their lines of enquiry. However this appears particularly necessary in the PD literature given that, whilst the role of the lexical-syntactic information is – by some, at least – considered core to differences between the word classes, there has yet (as far as can be established) to be any studies which have focused on the effect of grammatical complexity on verb processing in PD.

In summary, findings from the current aphasia literature appear mixed with regards to the effect of lexical-syntactic information at a single word level. Whilst different patterns present, these is an indication that a verb's transitivity (i.e., the number of arguments it takes) can influence retrieval at the single word level. What is less clear is whether that is because of the words' associated lexical-semantic richness, or a reflection of the lexical-syntactic complexity per se. Either way, the complexity of the lexical-syntactic information associated with verbs as compared with nouns is key to their differentiation according to word class. Thus, the fact that the influence of lexical-syntactic complexity on verb production in PD has yet to be considered appears somewhat of an oversight.

1.2.4 Complex (sentence and discourse level) processing in PD

Studies concerned with language at the sentence and discourse level in PD (i.e., 'complex' language) remain relatively few, with a greater number focusing on syntactic processing, through the assessment of sentence comprehension. Whilst some lines of exploration have been led by specific hypotheses regarding the role of basal ganglia in language processing, when it comes to complex language *production*, studies have tended to be broader and more exploratory in nature. This, at least in part, potentially reflects the fairly exploratory way in which the subject was initially approached (and consequently the way in which the field has progressed) and the fact that there is a greater variability in findings than has been seen in the verb production literature. Whilst, as again previously mentioned, there has been little overlap between the field of enquiry investigating verb processing and sentence and discourse level production, the two fields have broadly been concerned with the same questions. That is, are observed language alterations linguistic in nature or do they reflect 'broader' cognitive alteration.

In this section, an overview of the findings from across the literature will first be presented, before consideration is paid to the theories proposed to account for the language alterations seen, in relation to the evidence available. Studies of production will be focused on here, however comprehension studies will be referred too, where findings are pertinent to the discussion.

Fluency

An alteration in the fluency of sentence production (both in a single sentence and discourse context) has been reported in a number of studies, as measured through an increased number of pauses (Illes, Metter, Hanson, & Iritani, 1988; cf. Alvar, Lee, & Huber, 2019; Lee, Huber, Jenkins, & Fredrick, 2019) and breath pauses (Huber et al., 2012), increased pause (Alvar et al., 2019; Illes et al., 1988; Illes, 1989) and inspiratory duration (Huber & Darling, 2011), a greater number of mazes (re-starts, word repetitions and deviations; Huber et al., 2012) and a greater number of 'dysfluencies' (encompassing combinations of filled and unfilled pauses, false starts/restarts, sound repetitions and mazes; Lee, 2017; Troche & Altmann, 2012).

Although not necessarily representing a disparity, research within which dysfluencies have been grouped differently and/or considered individually present a slightly more nuanced picture. Work by Huber and Darling (2011), for example, found no significant difference in the number of dysfluencies (considered by them to be the repetition of sounds, syllables or single words) in the speech of individuals with PD as compared with controls. However they did see a significant difference in formulation errors – that is, the number of repeated phrases, revised and abandoned utterances. It is interesting too, that both within this same work by Huber and Darling (2011) and in a previously referenced study conducted by Alvar et al. (2019), significantly fewer filled pauses were evident in the speech of individuals with PD. The latter authors discussed this in relation to the reduced ability of individuals with PD to automatically respond to the presence of formulation difficulties (through marking them with a filler) and the role of the basal ganglia in automatic behaviours.

As previously alluded to, it is difficult to assess whether the difference in findings between Troche and Altmann (2012) and Huber and Darling (2011) are in conflict – or whether the same errors observed by Huber and Darling (2011) are also weighting the differences seen in the more general dysfluencies measured by Troche and Altmann (2012). A clearer disparity arises however between studies reporting on the number of recorded pauses; an increase in which was reported by Illes et al. (1988) but not seen in the work of either Alvar et al. (2019) or Lee et al.

(2019). There is the potential that this could reflect differences in task; whilst both latter studies utilised a story retelling task, the former analysed extracts of spontaneous speech, guided by questions from the researcher regarding the individual’s occupation, travel, and their childhood years. One could hypothesise that these more autobiographical questions – which require consideration and retrieval of information form long-term memory – would, in general, lead to a greater number of pauses. Why such a hypothesised effect might be greater in PD, in the absence of dementia is less clear, and potentially worthy of further investigation (although it should be noted that the cognitive status of individuals in Illes et al.’s 1988 study was self-reported).

There is the possibility too, however, that the difference in findings between these studies reflects differences in the period of silence each set of authors considered to be a pause. In both Alvar et al.'s (2019) and Lee et al's. (2019) work, silences of 150ms or greater were considered to be a pause, whereas Illes et al. (1988) considered a hesitation to be a period of 200ms or more of silence. Given the fairly consistent evidence to suggest that pause duration is greater in PD as compared with controls, this seemingly slight difference could be key to the presence (or lack thereof) of a significant difference in the number of pauses between individuals with PD and controls. If we suppose that more controls than individuals with PD are likely to exhibit pause lengths between 150ms and 200ms in length, this difference might have significantly increased the number of pauses shown by controls, thus diminishing, or in this instance eradicating, any difference in the number of pauses between individuals with PD and controls in the Alvar et al.’s and Lee et al.’s study. Both theories are speculative – but present potentially plausible explanations for the differences in findings seen.

Amount and informativeness of content

Findings regarding the length and duration of utterances provided by individuals with PD is slightly inconsistent. A majority of studies have reported no difference in the number of words (Alvar et al., 2019; Murray, 2000) or sentences/utterances (Lee et al., 2019; Murray, 2000) provided by individuals with PD, or reduction in the length (as measured through mean length of utterance [MLU]; Alvar et al., 2019; Dick, Fredrick, Man, Huber, & Lee, 2018; Murray, 2000; Roberts & Post, 2018; Vanhoutte, De Letter, Corthals, Van Borsel, & Santens, 2012) or duration (Alvar et al., 2019) of utterances. Some however have reported the production of shorter utterances and phrases in PD (Batens et al., 2014, 2015; Cummings, Darkins, Mendez, Hill, & Benson, 1988) or trend towards such an effect (Murray & Lenz, 2001). Again, there is an indication that this difference in finding may be linked to task. The studies reporting a difference in utterance/phrase length (or trend towards significance) examined spontaneous speech samples, whilst those which did not report such a difference employed more ‘constrained’ tasks; namely story retelling and discourse production from a picture stimulus.

This difference could be hypothesised to be one of constraint; that is, when the number of possible responses are limited, no difference in utterance length is observed between individuals with PD and controls, however when the options of what can be said is unlimited (potentially introducing greater selection and control demands, though an increased choice of verb) more is said by controls. It could, too, reflect differing cognitive and pragmatic demands between the tasks. It is interesting for example that, in their work looking at production in PD, Holtgraves, Fogle, and Marsh (2013) reported evidence to suggest that the reduced informativeness of sentences produced by individuals with PD observed was linked to the ability of individuals with PD to recognise speech acts and the amount of information required in response to them. The authors did not measure utterance length in this study, but it seems entirely plausible that the amount said more broadly – as reflected through utterance length – could equally be affected by speech act recognition in PD.

There is the potential that utterance length could be affected, too, by the ability of individuals with PD to align with their interlocuters at a syntactic level. It has been proposed that dialogue is able to proceed in the un-effortful way that it does through a process of (largely) automatic lexical and syntactic alignment which ultimately allows for the alignment of situation models (i.e., the shared reference and understanding of whatever it is under discussion; Branigan, Pickering, McLean, & Cleland, 2007; Pickering & Garrod, 2004). There is some indication that syntactic alignment may be modulated by the allocation of attentional resources (Branigan et al., 2007; Horton, 2014). Given that attentional control process have been indicated to be vulnerable in PD (e.g., Dirnberger & Jahanshahi, 2013) the potential therefore arises that syntactic alignment may be affected in PD, leading individuals with PD to say less than controls because they are not aligning and mirroring the longer syntactic structures used by their interlocutor.

To our knowledge, to date no studies manipulating the executive function and/or broader cognitive demands of conversational discourse in PD have been conducted (for an example paradigm exploring the influence of executive functioning demands on the discourse of individuals with traumatic brain injury, see Byom & Turkstra, 2017). Such a study might provide a clearer idea of the influence of executive and cognitive demands at a discourse level in PD and – through providing a measure of the executive and broader cognitive demands – allow for more direct comparison between different lexical tasks.

The informativeness of the content provided by individuals with PD has been of interest within a small number of studies. Cummings et al. (1988), Murray (2000) and Roberts and Post (2018) all reported a reduction in informativeness of the output of individuals with PD. Relatedly, Troche and Altmann (2012) observed reduced ‘completeness’ scores, which measured whether individuals mentioned all actors shown in the picture, as well as the action taking place. In some contrast however, whilst individuals with PD within Lee et al.'s (2019) study also produced a lower number of correct information units, the difference as compared with controls did not reach significance. Furthermore, whilst it is difficult to assess the ‘informativeness’ of this content (in terms of the relevance and appropriateness in relation to the topic under discussion), it is interesting that Illes et al. (1988) and Illes (1989) both reported an increase in the use of open class, optional phrases by individuals with PD. The authors suggest this reflects a compensatory mechanism for the motor speech difficulties experienced by the individuals in their study (Illes et al., 1988) and processing load (Illes, 1989).

Whilst all the studies found a trend in the same direction, differences between the findings reported by Murray (2000) and Roberts and Post (2018) and those reported by Lee et al. (2019) could be linked to measurement tool utilised, and the potential confound of fluency (in terms of false starts and restarts, particularly) on that measure of informativeness. In all three of the studies, informativeness was assessed through calculating the percentage of correct information units, according to the procedure developed by Nicholas and Brookshire (1993). Under this method, “dead ends, false starts, or revisions….” are not considered to be correct information units (Nicholas & Brookshire, 1993, p. 348); such that a text high in revisions would have a lower percentage of correct information units, and a lower informativeness score. There is the possibility therefore that the lowered informativeness score is being distorted by an alteration in fluency. The fact that the difference on this measure between individuals with PD and controls was significant in Murray (2000) and Roberts and Post's (2018) studies but not in Lee et al.'s (2019) study may reflect differences in fluency between the groups. It is not possible to establish the likelihood of this hypothesis however, given that none of the studies measured word revisions or false starts.

As previously alluded to, it is difficult to directly compare the potentially contrasting findings reported by Illes et al. (1988) and Illes (1989) with those reported by Murray (2000), given that that the relevance and informativeness of the optional open class words reported by the former studies is not made clear. However, it is interesting to consider the finding of these former studies in relation to that of Troche and Altmann (2012), who found that individuals with PD had lower completeness scores, which the authors discussed in relation to a greater reliance on closed class words (in this instance, pronouns). Again, this difference could be one of task. In Troche and Altmann's study, individuals were asked to produce a sentence in response to a picture, meaning that significantly greater lexical constraint was exerted than in the spontaneous speech task of both Illes (1989) and Illes et al.'s (1988) studies. The fact that a noun naming deficit has not typically been seen in individuals with PD without accompanying cognitive impairment at a single word level suggests that the greater reliance on pronouns is not reflecting a noun-retrieval deficit per se, but could be reflecting increased linguistic (in terms of the verb required to form the sentence, and its associated retrieval costs) and cognitive demands.

Grammatical completeness and syntactic complexity

In two of the previously mentioned studies, a reduction in the proportion of grammatically complete sentences was observed (Murray, 2000; Troche & Altmann, 2012). These findings appear however to be outweighed by the number of studies who have not reported such a finding – either through experimental tasks (Dick et al., 2018; Illes, 1989; Lee et al., 2019; Murray & Lenz, 2001; Vanhoutte et al., 2012) or through the application of language assessment specifically investigating the production of argument structure (Lee, 2017). Similarly, when considering the syntactic complexity of utterances, whilst some studies have reported a reduction in complexity (Cummings et al., 1988; Illes et al., 1988) a greater number have not reported such a finding (Dick et al., 2018; Illes, 1989; Lee et al., 2019; Murray, 2000; Murray & Lenz, 2001; Vanhoutte et al., 2012). One study indicated that individuals with PD actually used more subordinate structures than controls (García et al., 2016). Interestingly, a more consistent effect of syntactic complexity has been seen within studies concerned with comprehension (Angwin et al., 2005; Colman, Koerts, Stowe, Leenders, & Bastiaanse, 2011; Grossman et al., 2002); an interesting finding, given the evidence to suggesting a functional and neuroanatomical overlap between comprehension and production processes; Pickering & Garrod (2013).

1.2.4.1 Complex language processing in PD: the influence of other cognitive processes

A small number of studies investigating language production in PD have included additional, experimental cognitive measures, whether that be measures of general cognitive functioning (in relation to the presence of dementia) or tasks tapping specific processes. Whilst some commonalities emerge, once again a number of differences in findings present. It is interesting, for example, that dementia severity was found to correlate significantly with the proportion of syntactically complex sentences in Murray and Lenz's (2001) study. Yet, Cummings et al. (1988) reported reduced syntactic complexity in individuals with PD both with and without dementia, and no significant difference in performance on this measure between groups. In their earlier work, Murray (2000) found a significant relationship between information content and dementia severity whilst – in some contrast to Murray and Lenz (2001)

– syntactic complexity (as measured through the number of embeddings per sentence) was associated more specifically with visual attention and short term memory ability. Somewhat similarly, whilst in Murray and Lenz's (2001) study MLU was also found to be associated with dementia severity, in Murray's earlier (2000) study, this measure was again found to be associated with short term memory, but not with dementia severity per se. There is the potential that this difference is reflective of task; the cognitive load in the picture description utilised by Murray (2000) is likely to be less than the spontaneous speech task utilised by Murry and Lenz (2001), thus reducing overall cognitive demand.

As mentioned above, in some contrast to studies concerned with production, difficulties with processing complex syntactic structures have been fairly reliably observed in studies concerned with comprehension. Whilst some authors have concluded that this finding reflects an alteration in the ability of individuals with PD to apply grammatical rules (Lieberman et al., 1992), in the main this finding has been attributed to factors other than grammatical processing per se. A study by Friederici, Kotz, Werheid, Hein, and von Cramon (2003) for example, investigated event-related potentials (ERPs) during sentence comprehension in individuals with PD. It was found that, whilst early, automatic syntactic processes appeared intact, there was an alteration in late, integration processes in individuals with PD, as indicated by an altered P600. This finding can be considered in relation to the role of executive control in language processing.

Whilst variation in the exact mechanisms exists, a number of authors propose that during comprehension, a number of possible, competing interpretations can arise (see Hochstadt, Nakano, Lieberman, & Friedman, 2006 and Ye & Zhou, 2009, for discussion), from which the correct representation must be selected. As discussed earlier in Section 1.2.3.3, this process is reliant on executive control. Given the findings from a number of studies indicating that set shifting ability is significantly correlated with the comprehension of certain complex syntactic structures in PD, one potential hypothesis is that individuals with PD have a reduced ability to move away from the representation built through expectation based heuristics, leading to an incorrect interpretation (Hochstadt, 2009; see also Grossman, Lee, Morris, Stern, & Hurtig, 2002). An alternative hypothesis – again linked to executive control – is that the difficulty in comprehending certain embedded constructions reflects an impaired ability to switch between foreground (i.e., information contained within the independent clause) and background (encapsulated within the relative clause) information. As such, the background, contextual information is unable to be successfully integrated in order for a correct representation to be established (Hochstadt, 2009; see also Colman et al., 2011 and Lee et al., 2003 for related findings [regarding attentional allocation] and discussion). Elsewhere, altered comprehension in PD has been separately linked to the presence of delayed semantic activation (Angwin et al., 2005; Grossman, Zurif, et al., 2002) and an impairment of temporal processing (Kotz & Gunter, 2015; Kotz & Schmidt-Kassow, 2015).

Work by Lee (2017) provides some interesting findings in relation to cognitive control demands and the fluency of speech. Whilst showing only a trend towards significance with Bonferroni correction applied, the aforementioned authors found that the number of dysfluencies produced in response to ‘low codability’ objects – i.e., objects which could take a variety of names – was greater in the PD group, as compared with controls, whilst no such difference in fluency existed for sentences constructed using high codability objects (Lee, 2017). Thus, whilst only tentative conclusions can be drawn, there is an indication that selection demands may not only influence accuracy at a single word level (see Section 1.2.3.3) but be contributing to the presence of dysfluencies within the production of a simple sentence.

Somewhat relatedly, it is interesting that early work by Lewis, Lapointe, Murdoch, and Chenery, (1998) found that individuals with PD (in the absence of cognitive impairment) showed a reduced ability to produce a sentence from given words. This pattern has also been reported in an individual with dynamic aphasia following a left basal ganglia infarct (Crescentini, Lunardelli, Mussoni, Zadini, & Shallice, 2008). In this latter study, the difference in performance was most pronounced when the individual was asked to produce sentences from two loosely associated words, which brought with them a greater number of conceptual options. This pattern has also been observed in other individuals with dynamic aphasia, through both this and slightly adapted tasks (Bormann, Wallesch, & Blanken, 2008; Robinson, Blair, & Cipolotti, 1998). This characteristic has been attributed to alteration at the conceptual level of production; more specifically, to the macro level of planning, during which the information to be included in the message is selected, before elements such as aspect and propositional structure are applied, to form the pre-verbal message (Bormann et al., 2008). Whilst it is fully appreciated that one cannot automatically extend findings reported in a case study of an individual with a basal ganglia lesion to individuals with PD, the finding that the language impairment observed was linked to situations within which high selection demands were placed clearly presents an interesting parallel. Furthermore, whilst not looking specifically at selection demands, it is interesting, too, that both Illes (1989) and Huber and Darling (2011), upon observing a pattern of long pauses prior to sentence onset in PD during spontaneous speech, put forward the possibility that this finding may reflect an impairment of planning – suggesting conceptual level processing in PD may be worthy of further investigation.

In summary, whilst available evidence is limited, the findings presented here suggest that selection demands may – as discussed in relation to single word processing – be contributing to the alterations in sentence processing observed. Significantly more research is required however before any firm conclusions can be drawn.

1.2.4.2 Complex language processing in PD: the linguistic hypothesis

As part of their study investigating sentence production in PD, Troche and Altmann (2012) found that, whilst executive functioning and working memory accounted for much of the variance in language production observed, when these cognitive measures were controlled for, significant differences in fluency, grammaticality and completeness remained (see also Altmann & Troche, 2011, for further discussion). It is possible, as the authors point out, that this may reflect a limitation of the tasks chosen, and their ability to fully, or accurately, capture the cognitive processes which may be accounting for altered language production in PD. However it presents the possibility, too, of the presence of a 'pure' linguistic deficit (Troche & Altmann, 2012). As previously discussed in Section 1.2.3.3, considering this finding in terms of the deficit in PD being 'linguistic' or 'cognitive' in nature is likely overly simplistic. Yet, if we are to assume that executive functions and working memory play an important and necessary role in language processing, the fact that they do not solely account for the language alteration observed by Troche and Altmann (2012) leaves us with the possibility that another component of the language processing system is also impaired in PD. And, given the previously considered findings from the literature looking and single word production in PD – one could hypothesise a role of altered verb processing.

To date, no studies have explicitly examined the impact of the characteristics of the verb around which the sentence is built – whether that be semantic meaning, or grammatical complexity – on production. It is interesting that, whilst the study mentioned above conducted by Troche and Altmann (2012) found an alteration in grammaticality (related primarily to the omission of initial determiners), the majority of studies have not found evidence of an impairment of grammatical processing in PD *per se*. This difference in findings between studies has been discussed by Dick et al. (2018) in relation to differences in the number of propositions within the task materials, such that the deficit seen by Troche and Altmann (2012) may not actually be reflecting altered grammatical processing, but be reflective of lexical selection and retrieval difficulties (see also Lee, 2017, for related discussion). This hypothesis warrants further investigation; there is certainly evidence to suggest that individuals with PD are able to successfully access the lexical-syntactic information accompanying a verb. However, there remains the possibility that the transitivity of a verb may influence production at a sentence level, if one considers grammatical complexity in relation to semantic richness and the number of related conceptual options. Rather than being seen through grammatical errors, however, one might expect such an effect to delay processing and, as a consequence, lead to a reduction in fluency of the type reported by Lee (2017), for example. Bearing in mind the discussion presented earlier regarding sentence production alteration in post stroke aphasia, comparing production in situations within which verb retrieval demands are removed through provision of the verb and those within which retrieval is required could be elucidating in this regard.

It is interesting, too, to consider the findings of Grossman, Stern, Gollomp, Vernon, and Hurtig (1994), here. These authors were interested in the ability of individuals with PD to learn a novel verb, and its accompanying lexical syntactic information.

Following a period of exposure to the new verb – “wamble” – individuals were asked to complete a sentence judgement task. The task comprised a series of sentences, including a number containing the newly learnt verb. Within a proportion of these sentences, the verb was used correctly – i.e., the word was acting as a verb, and conformed to the allowable lexical syntactic structure outlined during the exposure period. In another proportion of sentences however, the new verb was used incorrectly: sometimes acting as a noun or preposition (i.e., occupying the wrong word class) and at other times acting as a verb, but taking an unallowable syntactic argument structure.

Findings indicated verb learning to be impaired in PD, with accepting sentences which contained ‘wamble’ as a noun as correct found to be a relatively common error in the PD group. Whilst attributed to working memory impairment in some individuals, this finding was discussed by the authors in relation to altered grammatical processing in individuals with PD. However, as a comparable condition considering the learning of nouns (or any other word class for that matter) was not included, it is difficult to establish whether this over-generalisation reflects an impairment in the ability to appreciate the grammatical class of ‘verb’ per se, or a more general difficulty in word learning. Indeed, the same could be said for appreciating the grammatical, argument structure information included within the verb. Without comparing this to individuals’ ability to learn and appreciate the lexical-syntactic information associated with nouns (bearing in mind this is significantly less than that of verbs, especially in languages such as English which do not consider gender) it is difficult to categorically state that the findings reflect an altered ability to appreciate the grammatical information contained within verbs, rather than a general difficulty in learning the information associated with words.

When considering the impact of lexical selection on sentence production, it is important, too, to consider the role of semantics – namely the level of action associated with the verb's meaning. The potential impact of this, at a sentence level, is interesting to consider. The fact that sentence production in PD, whilst showing some alteration in terms of speech fluency, amount said and informativeness, by and large appears to be grammatically intact, suggests that individuals are able to access grammatical information, via the semantic lexicon. Presumably, then, in any instances where the semantic representation of an action may be compromised, individuals are able either to describe the target concept in an alternative way, or in some instances access it across a delayed time course; otherwise one would expect to see the level of sentence level impairment seen in individuals with aphasia, which is not the case. As touched upon above however, it seems reasonable to hypothesise that sentences produced around high action verbs might –- as the result of the high action, verb processing impairment –- be more 'subtly' altered, demonstrable potentially through altered fluency, or reduced utterance length or informativeness.

In summary, there is some indication that the sentence production impairment seen in PD may be at last partly 'linguistic' in nature. To date, no studies have investigated the effect of altered verb processing in PD – whether that be in relation to the motor content of the verb, or the number of conceptual options it encompasses – on sentence production.

1.2.5 Theoretical Background: Overall Summary

Verb Processing in PD

Findings from a number of studies indicate that verb processing may be vulnerable in PD. Questions remain regarding what is underpinning this alteration. One theory put forward to explain the deficit links to ideas of embodied cognition; that is, that the same networks involved in producing movement/action are also involved in the conceptual representations of such movement/actions. Under this theory, damage to motor networks – such as that seen in PD – could also result in an impairment of action word processing. For this to explain the verb deficit in PD however, it would have to be demonstrated that ‘action’ verbs are specifically vulnerable, as opposed to ‘verbs’ more broadly. Whilst there is some evidence to this effect, current findings would suggest that the verb processing alteration attributable to motor-network damage is fairly limited, and specific in its nature. Thus, questions remain regarding what else may be contributing to the broader verb/noun dissociation seen in PD.

Another hypothesis relates not to the semantic meaning of verbs, but the complexity of them – both in terms of the number of conceptual and word form options – as compared with nouns. Specifically, it is proposed that the verb difficulty seen in individuals with PD may reflect an impairment of the executive control processes necessary to effectively inhibit competing alternatives. This theory does not disprove the motor hypothesis. Indeed, as has been discussed within the literature, it could be the case that both are contributing to the alterations seen, dependent to a degree on the demands of the task.

The final theory considered is that of word class – i.e., that verbs are fundamentally different to nouns, irrespective of the semantic confound. Unlike nouns, verbs carry lexical-syntactic information specifying argument structure and thematic role assignment. There is debate regarding when this lexical syntactic information becomes available. However, if as has been argued, lexical-syntactic information is available during single word processing, both the very presence of such information and the required processing of it could explain why verbs – as compared with nouns – are more difficult to retrieve. Grammatical complexity – measured both through the number of arguments that can be taken by a verb, as well as the complexity of the argument structure – has been shown to influence production in aphasia. To date, the impact of the grammatical complexity of verbs has not been explored in PD. If the pattern is similar to that seen in aphasia, it would be expected that difficulties with retrieval would increase as grammatical complexity increases – i.e., as the number of syntactic arguments taken by the verb increases, or in instances where the verb's argument structure requires movement of a sentence element from base position.

Sentence Construction in PD

Generally, findings regarding alteration in the complex (i.e., sentence and discourse level) language production of individuals with PD are mixed. Alterations in fluency (including pause length), the amount and informativeness of content and grammatical completeness have all been reported in some studies but not in others; potentially reflective both of differences in the way the elements of interest were measured, and to differences in task demands. Current findings would suggest that whilst both general cognitive decline and alteration in specific cognitive abilities may be linked to the language alterations seen, there is some indication, too, that such alterations remain when cognitive difference is controlled for. As far as can be established, to date no studies have explicitly explored the potential influence of altered verb processing in PD on sentence construction.

1.3 Study Aims

From the literature reviewed in the preceding sections, a number of knowledge gaps present. Arguably the most noticeable of these is the current gulf between research concerned with single word and sentence level processing in PD, and the lack of studies investigating the potential influence of grammatical complexity (both in terms of the number of syntactic arguments taken by the verb, and the complexity of the structure of those arguments) on verb processing in PD – an oversight, given the potential light this may shed regarding the root of the specific verb processing deficit observed. More generally, exploration into what might be underpinning language alteration in PD at a sentence level is in its infancy. A number of questions regarding both the linguistic factors which may be influencing sentence production in PD and the role of supporting cognitive processes remain – as well as questions regarding the influence of task on language production in PD, and what might be underpinning such influence.

With these points in mind, the aims of this research were to investigate in a group of individuals with PD without dementia or indication of global cognitive decline:

1. the influence of a verb's grammatical complexity and action level on verb production at both a single word and sentence level
2. the influence of a verb's grammatical complexity and/or associated action, and conceptual/message level processing, on sentence construction
3. language performance across tasks which differ in their nature and linguistic demands
4. the relationship between measures of verb and noun production accuracy, sentence construction and core cognitive abilities

1.3.1 Research Questions and Hypotheses

From these aims the four research questions addressed within the research were formed. Each of these aims has a corresponding set of research questions and hypotheses, as outlined below.

RQ 1. What is the influence of a verb's grammatical complexity on verb production in PD, and how does this interact with the verb's action content, at both a single word and sentence level?

RQ 1.1. Does the grammatical complexity of a verb influence production in PD?

Hypothesis: The production of verbs which are more grammatically complex, either in relation to the number of syntactic arguments they take or the structure of those arguments, will be altered in PD. No effect of grammatical complexity on production will be seen in the control group.

RQ 1.2. Does the grammatical complexity of a verb interact with any effect of the action associated with the verb's meaning in PD?

Hypothesis: An interaction between action and the number of syntactic arguments that can be taken by the verb will present in PD, such that the retrieval of high action, grammatically complex verbs will be impaired. No effect of action, grammatical complexity or interaction will be seen in the control group.

RQ 1.3. Do verb production difficulties present at both a single word and sentence level in PD?

Hypothesis: Verb production difficulties will be evident at both a single word and sentence level in PD.

RQ 2. Can altered verb or conceptual level processing explain any change in sentence construction in PD, as measured through fluency, lexical content, and response time?

RQ 2.1. What is the influence of the level of action associated with a verb on sentence construction in PD?

Hypothesis: Sentences produced by individuals with PD in response to pictures depicting high action verbs will be shorter, of lower lexical density, less fluent, and take longer to formulate. No effect will be evident in the control group.

RQ 2.2. How does the number of syntactic arguments taken by a verb influence sentence construction in PD, and does this interact with the level of action associated with the verb?

Hypothesis: An interaction between the number of syntactic arguments that can be taken by the verb and action will be observed in PD, such that sentences produced using grammatically complex, high action verbs will be shorter, of lower lexical density, less fluent, and take longer to formulate. No effect will be evident in the control group.

RQ 2.3. Can an alteration in conceptual level processing explain any alteration in sentence construction in PD?

Hypothesis: Alterations in conceptual level processing will present in PD, leaving sentences produced in response to words providing more conceptual options being shorter, of lower lexical density and less fluent. No such effect will be evident in the control group.

RQ 3. What influence does the nature and linguistic demands of a task have on language production in PD?

RQ 3.1. Is there a difference in verb production accuracy in PD according to whether the task is eliciting production at a single word or sentence level?

Hypothesis: Verb accuracy will be reduced in a sentence as compared with a single word context, in the PD group.

RQ 3.2. At a sentence level, is there a significant effect of stimulus type (e.g., a picture versus a given verb) on sentence construction in PD?

Hypothesis 1: Sentences provided by individuals with PD in response to a picture will be shorter, of lower lexical density, take longer to formulate and be less fluent than those produced in response to a given verb. No such effect will be evident in the control group.

Hypothesis 2: Sentences created by individuals with PD, using a given word-pair, will be less fluent than those produced in response to a single verb. Again, no difference in the sentences produced according to stimuli type will be evident in the control group.

RQ 4. What relationship exists between language processing and measures of executive functioning, verbal short term and working memory, and processing speed in PD?

RQ 4.1**.** What is the relationship between noun and verb production accuracy and measures of executive functioning, verbal short term and working memory, and processing speed in individuals with PD?

Hypothesis: Relationships between verb and noun production and measures of executive functioning and working memory (i.e., storage and manipulation of information) will be evident in the PD group. No prediction is made regarding relationships between noun and verb production and cognitive ability in the control group.

RQ 4.2. What is the relationship between sentence construction and measures of executive functioning, verbal short term and working memory, and processing speed in PD?

Hypothesis: Relationships between measures of sentence construction and core cognitive abilities will be evident in the PD group. No prediction regarding the relationship between core cognitive abilities and sentence construction in the control group has been made.

This chapter has provided an overview of the current literature regarding language alteration in PD. Gaps in current knowledge were identified leading to the rationale, study aims and research questions outlined above. The methods employed to address these questions are presented in the next chapter.

2 General Methodology

This chapter details the overarching methodology adopted within the study. It opens with a description of the overall design of the research (Section 2.1) followed by a full description of the participants involved, embedded within a broader description of the recruitment protocol followed (Section 2.2). An overview of the task battery is then provided (Section 2.3), leading on to a concluding section outlining the data analysis procedures (Section 2.4) followed across the research.

2.1 Research Design

This quantitative research compared the performance of 16 individuals with Parkinson's Disease (PD) with that of 25 education and age matched control participants across a combination of language and cognitive tasks. The influence of two primary conditions – linguistic characteristics and the nature of a task – were investigated through a combination of between-subjects, within-subjects and mixed factorial comparisons. Relationships amongst the cognitive and linguistic variables were explored through correlation analyses.

Whilst data collection was conducted as a whole over a number of testing sessions, the research can be seen as comprising four component studies. Each study employed designs appropriate to investigate the corresponding research question. Within each testing session, experimental tasks were interspersed with tasks designed to provide a general profile of linguistic and cognitive performance per group.

2.2 Recruitment Protocol

2.2.1 Ethical Approval

Approval for the study was granted by the West of Scotland NHS Research Ethics Committee (REC 3; REC reference: 16/WS/0215) and endorsed by the University of Strathclyde Ethics Committee. NHS Research and Development (R&D) approval was granted from the NHS board within which recruitment took place. Informed consent was obtained from all participants before they entered into the study.

2.2.2 Participant Recruitment

Individuals with PD[8] were recruited through Parkinson's UK and an NHS board located within central Scotland. In both recruitment pathways, individuals were provided with a participant information sheet (PIS; see Appendix A) and asked to contact the researcher directly if they were interested in taking part. Parkinson's UK shared information about the study via their website and research support network: an email service to which individuals can choose to sign up in order to hear about research opportunities. In the NHS recruitment pathway, potential participants were given information about the study from their clinician within a typical healthcare appointment.

Control participants were recruited through a volunteer panel run by the School of Psychological Sciences and Health within the University. Individuals, who had

[8] The diagnosis of PD was made in Scotland. At the time of recruitment, the clinical guideline 'Diagnosis and pharmacological management of Parkinson's disease', produced by the Scottish Intercollegiate Guideline Network, was active. This guideline – as a result of being over 10 years old – was withdrawn in 2020 and can no longer be accessed. A summary of the guidelines however remains available (Grosset, Macphee, & Nairn, 2010).

signed up to hear about research taking place across the School, were sent information about the study (PIS; see Appendix B) and asked to respond directly to the researcher if they were interested in taking part. Involvement was voluntary for all individuals however travel expenses were reimbursed upon request.

2.2.3 Exclusion Criteria

Study participants were required to be native English speakers, aged 50 years and above. They were additionally required to have adequate (including corrected) vision and hearing, no current diagnosis or indication of dementia or depression and no current diagnosis or history of any neurological conditions (other than idiopathic PD, in the patient group). The full list of exclusion criteria is outlined below. In the majority of instances, whether these criteria were met was at the discretion of participants. For the remainder – i.e., the criterion concerned with intelligibility, global cognitive decline suggestive of dementia and depression – screening tasks were utilised (see Section 2.2.4). If any individual with PD was unsure as to when they received the diagnosis, consent was gained from them to allow the researcher to contact an appropriate healthcare professional in order to obtain this information.

Individuals were unable to take part in the study if:

- They were aged below 50 (and/or, in individuals with PD, if they had been diagnosed with PD before the age of 50)
- They were non-native speakers of English
- They had a diagnosis of dementia or an indication of global cognitive decline, potentially suggestive of dementia
- They had a diagnosis of depression, or an indication of low mood/depression
- They had severe dysarthria and/or any (pre-morbid, in the case of individuals with PD) speech and/or language impairment

- They had been diagnosed with any other neurological condition or had a previous brain injury (e.g., stroke)
- They had a visual or hearing impairment (that was not corrected through glasses or a hearing aid)

Individuals who had a diagnosis of any Parkinsonism Syndrome other than idiopathic PD were excluded. Additionally, individuals with PD who had received Deep Brain Stimulation were excluded from the study.

2.2.4 Screening Tasks

2.2.4.1 Speech Intelligibility

Intelligibility was judged perceptually by the researcher during initial conversations with individuals prior to the first session. No individuals were excluded due to concerns regarding intelligibility in either the pilot or main study.

2.2.4.2 General Cognitive Functioning

The Mini-Addenbrooke's Cognitive Examination (M-ACE; Hsieh et al., 2015 - form and scoring guidance retrieved from: https://sydney.edu.au/brain-mind/resources-for-clinicians/dementia-test.html and provided in Appendix C) was selected to assess individuals' general cognitive ability and detect any individuals whose level of cognitive functioning may be suggestive of dementia. The test is brief (5-10 minutes) and has been shown to be sensitive to detecting cognitive decline (Hsieh et al., 2015). The lower of the two recommended cut-offs (21/30) was utilised, due to its greater specificity[9].

The nature of the M-ACE and its purpose were made clear within the PIS provided to individuals prior to starting the study. The results from the M-ACE, with consent, were sent to each individual's GP, regardless of score. No individuals were excluded as a result of this procedure.

2.2.4.3 Mood and Wellbeing

Due to the impact that the presence of depression can have upon cognitive functioning (e.g., Costa, Peppe, Carlesimo, Pasqualetti, & Caltagirone, 2006; Hammar & Ardal, 2009; Uekermann et al., 2003), it was necessary to exclude any individuals who were experiencing low mood or depression from the study.

The Geriatric Depression Scale-15 (Yesavage & Sheikh, 1986; form retrieved from: https://dementiapathways.ie/_filecache/0c8/57e/37-gds.pdf and provided in Appendix D) was selected to assess individuals' mood. The short, self-rated scale focuses on the non-somatic symptoms of depressive disorder and has been shown in to be able to discriminate depressive disorder in PD (Weintraub, Oehlberg, Katz, & Stern, 2006). For control participants, the outlined cut-off of 5/6 was utilised. For the PD group, a cut-off of 4/5 was instead selected, in line with findings to suggest this cut-off to be optimal for individuals with PD (Weintraub et al., 2006). The nature of the task was made clear in the PIS and it was stressed that individuals were under no obligation to compete it, if for any reason they preferred not to. It was a necessary measure for the study however, thus it was also made clear that if

[9] For the M-ACE, two cut-off scores are recommended: 25 out of 30 and 21 out of 30. The lower cut-off was selected for the purposes of this study due to it having a specificity of 1.0.

individuals did not feel comfortable completing the task, they would not be able to continue on into the study. As with the M-ACE, the results from the GDS-15 were sent to all individuals' GPs, regardless of score.

It was necessary to exclude two individuals with PD from the study due their score on the GDS-15. In both instances, the findings were explained to the individuals concerned and they were encouraged to speak with a healthcare professional about them.

2.2.5 Participants

Forty-one participants took part in the main study: 16 individuals with PD and 25 control participants. Demographic information relating to each individual's age, gender and education was collected from all participants (see Appendix E). Clinical information relating to time since diagnosis, motor symptom presentation and medication was further collected from the PD group (see Appendix E). Education was grouped into three categories: school level education (category 1), some form of further education (i.e., a diploma or undergraduate degree; category 2) and postgraduate education (category 3).

There was no significant difference in demographic characteristics between the groups (see Table 1). Females outnumbered males in both groups, and, across the board, the majority of individuals had carried out some form of further education (81.2% of the PD group and 76.0% of controls). No significant difference in general cognitive ability (as assessed using the M-ACE), or mood and feelings of wellbeing (as assessed using the GDS-15) were evident between groups. Further, when the M-ACE broken down into subsections, performance did not significantly differ between groups in any domain (all $p > .26$).

Individuals in the PD group had been diagnosed between 1 and 22 years previously, with a majority reporting motor symptoms to be worse on their right side. Nearly all were taking PD-related medication, which in all cases included a form of Levodopa (see Table 1). Information pertaining to the stage of individuals' PD (using the Four Stage Pathway approach; see Thomas & MacMahon, 2004) could not be obtained for all participants and as such was not included.

Table 1.

Demographic and clinical characteristics of study participants

	PD Group (n = 16)	Control Group (n = 25)	p value
Age, *Mean (SD)*	71.9 (7.48)	72.8 (8.03)	.730[a]
Gender, *M:F*	7:9	7:18	.300[b]
Education, *Category1:Category2:Category3*	3:7:6	6:15:4	.294[b]
General cognitive ability, *Median (IQR)*	28.0 (5.0)	28.0 (4.0)	.523[c]
Mood and feelings of wellbeing, *Median (IQR)*	2.00 (1.75)	1.00 (2.50)	.196[c]
Years since diagnosis, *Mean (SD)*	6.98 (5.46)		
Side of body most affected at time of testing, *Right:Left:No Noticeable Difference*	9:5:2		
PD medication taken, *Yes:No*	15:1		

*p < .05, †p < .001

[a] *p value derived from an independent samples t-test*

[b] *p value derived from a chi-square test*

[c] *p value derived from a Mann-Whitney U test*

2.2.5.1 Additional Participant Information

Information regarding PD participants' day-to-day functioning and communication was additionally collected.

Day-to day Functioning

The Schwab and England Activities of Daily Living Scale (Schwab & England, 1969, retrieved from Perlmutter, 2009) was used to gain an understanding of each individual's daily functioning (see Appendix F). The tool is not specialised for the condition, but has been used frequently in studies involving individuals with PD (Ramaker, Marinus, Stiggelbout, & van Hilten, 2002). The scale runs from 100% (being completely independent) to 0% (fully dependent). Each individual's 'level' was decided by them, according to which descriptor they felt most accurately fitted their day-to-day functioning.

Ratings on the Schwab and England Activity of Daily Living Scale ranged from 60-100%. The majority of participants (14 participants, 87.5%) were clustered at 80-90%, indicating that they were able to carry out most if not all chores, with some awareness of certain activities starting to take longer.

Day-to-day Communication

A semi-structured interview schedule was developed to establish how the individuals with PD involved in the study viewed their day-to-day communication, and any difficulties they may experience. Because the aim of the interview was to provide some general background information and context to the detailed structured linguistic analysis conducted through the experimental tasks, the interview was purposefully kept brief. Further, in light of the amount of data already being collected across the study, questions were asked just to individuals with PD themselves (i.e., questions were not extended to communicative partners).

Word-finding difficulties was the element most commonly reported (11 out of 16 participants) however for many, this was reported as being mild and occasional, and not felt to be related to their PD. A few participants reported some change relating to planning (noticing more planning before speaking) or keeping the thread when telling a long story, however no difficulties with formulating sentences per se were noted. One participant reported having occasional mild comprehension difficulties, with the remainder reporting no noticeable change. The majority (11 out of 16) reported noticing some change in their speech, which some reported as causing some difficulty when talking in groups or noisy situations.

2.3 Materials and Procedures

2.3.1 Materials

Investigation of the four research questions required information about individuals' functioning within a number of specific cognitive and linguistic domains, and thus demanded tasks which tapped as precisely as possible into the cognitive/linguistic function of interest. Full details of the materials and procedures for each task can be found in proceeding chapters; information here (see Table 2 and Table 3) is intended to give an overall view of the task battery developed and utilised within the study, including those tasks used to gain a general profile of the groups' linguistic and cognitive abilities (henceforth referred to as the 'general profile'). Performance of some tasks was analysed using more than one measure, such that information from the same task was used to address more than one research question.

Table 2.

Task battery developed for the present research: Language measures

Task	Measure	Process	Section within which information was utilised
Nonsense-word reading	Response Time (RT)	Speech Initiation	General Profile (Section: 3.2.1)
Boston Diagnostic Aphasia Examination Subtests	Accuracy	Sentence Comprehension	General Profile (Section: 3.2.2)
Interview Schedule	Communication Difficulties reported	Day-to-day communication	General Profile (Section: 2.2.5.1)
Schwab and England Activities of Daily Living	Level of Functioning	Day-to-day functioning	General Profile (Section: 2.2.5.1)
Picture Naming Task (objects)	Accuracy; RT	Noun Production	General Profile (Section: 3.2.3) RQ 4 (Section: 7.2.1)
Picture Naming Task (actions)	Accuracy; RT	Verb Production	General Profile (Section: 3.2.4) RQ 1 (Section: 4.2.1) RQ 3 (Section: 6.2.1) RQ 4 (Section: 7.2.1)
Sentence Production Task	Accuracy; RT	Verb Production	RQ 1 (Section: 4.2.2) RQ 3 (Section: 6.2.1) RQ 4 (Section: 7.2.1)
	Fluency; Lexical Content; RT	Sentence Construction	RQ 2 (Section: 5.2.1)7.2.1 RQ 3 (Section: 6.2.1) RQ 4 (Section: 7.2.1)
Ergative Verb Sentence Production Task	Accuracy	Verb Production	RQ 1 (Section: 4.2.3)
	Fluency; Lexical Content; RT	Sentence Construction	RQ 2 (Section: 5.2.1) RQ3 (Section: 6.2.1)
One Word Sentence Generation Task	Fluency; Lexical Content; RT	Sentence Construction	RQ 2 (Section: 5.2.2) RQ 3 (Section: 6.2.1) RQ 4 (Section: 7.2.1)
Two Word Sentence Generation Task	Fluency; Lexical Content; RT	Sentence Construction	RQ 2 (Section: 5.2.3) RQ 3 (Section: 6.2.1)

Table 3.

Task battery developed for the present research: Cognition Measures

Task	Measure	Process	Section within which information was utilised
Shifting Task	Accuracy; RT	Attentional Set Shifting	General Profile (Section: 3.2.5.1) RQ 4 (Section: 6.2.1)
Stroop Task	RT	Inhibition	General Profile (Section: 3.2.5.2) RQ 4 (Section: 6.2.1)
2-back Task	Accuracy; RT	Updating	General Profile (Section: 3.2.5.3) RQ 4 (Section: 6.2.1)
Forwards Digit Span Backwards Digit Span	Capacity (Span)	Short Term Memory Working Memory	General Profile (Section: 3.2.5.4) RQ 4 (Section: 6.2.1)
Inspection Time Task	Accuracy	Processing Speed	General Profile (Section: 3.2.5.5) RQ 4 (Section: 6.2.1)

Images for all tasks containing picture stimuli were retrieved from Shutterstock (https://www.shutterstock.com/), under licence from the University of Strathclyde. Where required, information regarding word frequency, length and dominant position of speech was obtained from Subtlex-UK (http://crr.ugent.be/archives/1423), and information regarding a word's phonological (excluding homophones) and orthographic neighbourhood retrieved from the English Lexicon Project (http://elexicon.wustl.edu/). Ratings, collated by Kuperman, Stadthagen-Gonzalez, and Brysbaert (2012; accessed from http://crr.ugent.be/archives/806) were used to ascertain information regarding the age at which a word was typically acquired (age of acquisition; AoA), and ratings from Brysbaert, Warriner, and Kuperman (2014; accessed from http://crr.ugent.be/archives/1330) used to ascertain the words' concreteness. Visual complexity of the picture stimuli was estimated using the size of the JPEG file; an approach advocated by Bates et al. (2003) in response to concerns that ratings made subjectively can be confounded by familiarity.

2.3.2 Task Procedures

With the exception of the sentence comprehension task, all tasks were preceded by a short practice session, giving individuals the chance to become accustomed to the procedure. Again, with the exception of the sentence comprehension task, stimuli for all tasks were randomised using Microsoft Excel and delivered in the same order for each participant. All tasks were divided into blocks, and individuals encouraged to rest between blocks, as required.

Stimuli in all except the sentence comprehension task were presented on a Dell Latitude E6230 laptop using E-Prime Software (Psychology Software Tools, Inc.), chosen due to its millisecond presentation accuracy. All participants were seated at a table, with the laptop positioned immediately in front of them. A riser was used to ensure that the screen was at eye level for each participant. In all tasks within which response time (RT) was a measure, an audible beep (retrieved from: http://soundbible.com/291-Fuzzy-Beep.html) was sounded as the stimuli appeared on the screen; necessary to enable the verbal RT to be calculated. Participants were made aware of this in the task instructions and had time to become accustomed to the sound during the practice session.

Participants' responses in all tasks, with the exception of the sentence comprehension task, were recorded. This was primarily to enable RT to be calculated but was additionally necessary in the sentence construction tasks as it was not possible to document answers in real time.

2.3.3 Scoring

Accuracy

Accuracy was a dependent measure within the majority of tasks (see Table 2). In all instances, answers were marked against pre-set criteria, developed during formation of the task. Precise details of these criteria are provided in subsequent chapters. Answers provided in the single word noun and verb production task, and the cognitive tasks, were logged and scored in real time, using pre-designed answer scoring sheets.

Linguistic Analysis

Answers provided in the sentence construction tasks were transcribed at the earliest opportunity following completion of the task and analysed according to the linguistic measures of interest: fluency and lexical content (see Section 5.2.1 for detail).

To confirm reliability of the linguistic analysis conducted, data from a randomly selected 10% of participants from each participant group (i.e., data from two randomly chosen PD participants and from three randomly chosen control participants) were marked again by the original rater and by an external rater. The external rater was provided with an overview of the tasks as well as detailed information regarding the linguistic analysis procedure (see Section 5.2.1). To establish the level of agreement between these two separate ratings and the initial rating, intraclass correlation coefficients (ICCs; calculated using a single, absolute agreement two-way mixed effects model for both inter and intra rater reliability; Koo & Li, 2016) were utilised. When calculated using this model, the ICC is equivalent to Cronbach's alpha but allows a confidence interval to be calculated (IBM Support, 2018; Koo & Li, 2016). As evidenced in Table 4 below, agreement was high across all measures.

Table 4.

Inter and Intra-rater agreement for linguistic analysis measures

Rater	Linguistic Dimension	Intraclass Correlation	95% Confidence Interval		F test with True Value			
			Lower Bound	Upper Bound	Value	*df*1	*df*2	Sig
Inter	Fluency	.911	.905	.916	21.4	3598	3598	<.001
	Lexical Content	.996	.995	.996	470	2158	2158	<.001
Intra	Fluency	.975	.973	.976	77.9	3598	3598	<.001
	Lexical Content	.997	.997	.997	654	2158	2158	<.001

Response Time and Pause Length Calculation

Praat (version 6.0.30; Boersma & Weenink, 2017) was used to calculate RT in all tasks within which this was a dependent measure, and to measure the length of any medial pauses evident within the sentence construction tasks.

RT was calculated from the audio recordings as the interval between the onset of the beep signalling the presentation of each stimulus and the onset of a participant's response. Medial pauses were considered to be any pause equal to or longer than 200ms. To identify these durations, an inbuilt Praat script was run which identified any pause in the speech sample, including that between the beep and any spoken response. These pauses were then labelled according to function (e.g., RT, medial pause) and each checked manually to ensure reliability and to enable any necessary corrections to be made; for example, in instances where participants had coughed, made a slight false start, provided a verbal filler or made a slight vocalisation prior to their answer, or when the automatic marker had slightly missed the start of the utterance, due to nature of the speech sound at its onset.

2.3.4 Pilot Study

A small pilot was conducted to assess the suitability of the tasks and study procedure. Due to changes made as the result of the pilot, these participants were not included in the main study. Nine participants took part in the pilot stage of the study. The PD sample comprised three males and one female (59 – 72 years, *M* = 68.1, *SD* = 5.85; three of the four had undertaken an undergraduate or postgraduate degree) and the control group comprised one male and four females (57 – 77 years, *M* = 69.5, *SD* = 7.67; three of the five had undertaken an undergraduate or postgraduate degree). The groups were matched for age, $t(7) = -0.30$, $p = .774$, and education, $\chi^2(2) = 0.23$, $p = .894$.

Following the pilot study some changes were made to the materials, as fully described in Appendix G. Short practice sessions were included before all tasks (with the exception of the sentence comprehension task) and minor changes made to the instructions of the verb naming, sentence production, one word sentence generation and processing speed tasks. In the former two, individuals were asked to name the action as '*specifically*' as they could. In the sentence production and one word sentence generation task, participants were asked to "please say the sentence as soon as you can *once you have thought of it*" to avoid individuals starting the sentence then pausing to think. In response to feedback, in the processing speed task it was stressed that participants needed to be ready for the stimuli to appear after summoning them.

Minor changes were additionally made to a small number of picture stimuli, primarily the insertion of arrows and/or adjustment of aspect to highlight the object/action of interest. In the sentence production task, a sentence starter (e.g., 'the man is…') was included underneath all picture stimuli, in an effort to help steer participants to the actor in the picture carrying out the target action. Finally, *speed* was added as an independent variable in the updating task, with the length of the interstimulus interval (ISI) between stimuli presentation decreasing in the second two blocks.

2.4 Study Procedure

2.4.1 Testing Sessions

The tasks were carried out across three testing sessions, each lasting between 1 hour and 15 minutes and 1 hour and 30 minutes. The first session began with the screening materials required to confirm participants' eligibility for the study.

Necessary autobiographical information and information about participants' PD was also collected.

Assuming that individuals progressed through the screening tasks, within the remainder of the first session the speech initiation, sentence comprehension and noun naming tasks were carried out. For individuals with PD, the session always ended with discussion about how their PD affected their daily living, measured through the Schwab and England Activities of Daily Living Scale (Schwab & England, 1969, retrieved from Perlmutter, 2009). For all participants, the speech initiation task was delivered first, and the noun naming and sentence comprehension tasks delivered in an order randomised for each individual.

The remaining language and cognitive tasks were divided across the two subsequent sessions. The order in which tasks were delivered was randomised for each participant. The one word sentence generation and sentence production tasks did not appear in the same session however, and the verb naming and sentence production tasks also appeared in separate sessions. This decision was taken both because of potential priming effects and because the one word sentence generation and sentence production tasks are the longest to complete – thus there was concern that having both in the same session could result in fatigue. The language and cognitive tasks were interwoven, with half of participants starting with a cognitive task and the other half starting with a language task.

2.4.2 Session Arrangements

Testing sessions were arranged at the convenience of the participant. Sessions either took place within a quiet room (the Memory and Ageing Lab) within the University, or in participants' homes. PD medication can have a significant effect on performance within certain cognitive (Cools et al., 2003) and language (Herrera, Cuetos, et al., 2012) tasks. Thus, sessions were arranged as far as possible around individuals' medication schedule, to avoid testing taking place during individuals' "off-periods".

2.5 Data Analysis

2.5.1 Sample Size

The sample size necessary to ensure that a study is adequately powered is often calculated using values including effect size. Due to the novelty of this study, it was not possible to utilise effect sizes from previous studies (in instances where they were provided) and, whilst a pilot study was conducted, the small size of that pilot raised concerns regarding the reliability of any such calculated effect sizes (Leon, Davis, & Kraemer, 2012).

Whilst the size of the PD sample is approximately in line with a number of previous studies investigating language production in PD (Bocanegra et al., 2015 [N = 17 in MCI group & N = 23 in the non-MCI group; Herrera & Cuetos, 2012 [N = 20]; Troche & Altmann, 2012 [N = 19]) it is acknowledged that, due to the relatively small sample size (and the number of independent variables relative to that sample size), extreme caution needs to be exercised when carrying out and interpreting statistical analyses.

2.5.2 Design

A detailed description of the designs adopted for each research question are presented in subsequent chapters. For the experimental research, independent and repeated groups' designs were adopted in any instance within which the effect of a single variable was being explored. Where multiple variables were under investigation, factorial (primarily mixed factorial) designs were adopted. Correlation analysis was adopted to explore the relationship between measures of interest.

2.5.3 Analysis Software

IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., 2016) was used to carry out the statistical analysis.

2.5.4 Statistical Analysis

For the majority of investigations, more than one independent variable, and any interaction between these variables, was of interest. For these investigations, two and three-way mixed factorial analyses of variance (ANOVAs) were planned.

However, the majority of the data failed the assumption of normality (and, in some instances, other assumptions were additionally violated). Whilst there is fairly strong evidence to suggest that one-way ANOVAs are robust to violation of the assumption of normality (Blanca, Alarcón, Bendayan, Arnau, & Bono, 2017), the same cannot be said for repeated measures ANOVAs, with research suggesting an increased type I error rate when the assumption is violated (Oberfeld & Franke, 2013). Little is known about the robustness of mixed factorial ANOVAs; thus, conclusion regarding their reliability was made from the assessment of univariate one-way and repeated measures ANOVAs just outlined which would, in any respect, be required to follow them up anyway.

Data transformation is one method to deal with data which is non-normally distributed. This option was considered however, due to concerns regarding the relevance of results conducted on transformed data (Feng et al., 2014), this approach was avoided. Another option considered was conducting robust statistics using 20% trimmed means (Mair & Wilcox, 2019) however, due to concerns about the number of observations in the within-subjects comparisons (the number of observations per group was only seven in the action-grammatical complexity conditions, significantly less than the 20 suggested by Wilcox [1995, cited in Keselman, Kowalchuk, Algina, Lix, & Wilcox, 2000]) this option was also not felt to be suitable. Final consideration was paid to the option of conducting multiple non-parametric analyses to investigate each of the main and interacting effects (i.e., the effect of each level of each factor on each level of the other factors) however this approach was not adopted due to concerns, even with Bonferroni adjustment applied, about ‘fishing’ in the data.

The following protocol was consequently followed. Mixed factorial ANOVAs were run as originally planned *but* with precautions in place. Main and interaction effects from the ANOVA were reported and followed up according to the protocol illustrated in Figure 2, with Bonferroni correction applied[10]. The data for any significant main effects and all follow up comparisons – including any pairwise comparisons conducted following evidence of a significant main effect – were checked independently to see if they met the necessary assumptions for parametric testing. If any assumptions were violated, equivalent non-parametric analyses were run, and these findings additionally reported (bearing in mind the reduced power of non-parametric tests). The non-parametric tests utilised were as follows:

Repeated measures analyses

Freidman tests followed up by Dunn’s pairwise comparisons as required.

[10] In the case of pairwise comparisons conducted following evidence of a significant main effect, automatic *p* value adjustment was applied within SPSS, thus maintaining alpha at .05.

Paired-sample comparisons

Wilcoxon Signed Rank or Sign tests, according to the distribution of differences.

Independent sample comparisons

Mann-Whitney U tests. Where group distributions were different, mean ranks were reported. If any ties were present in the data, asymptotic significance values were referred to.

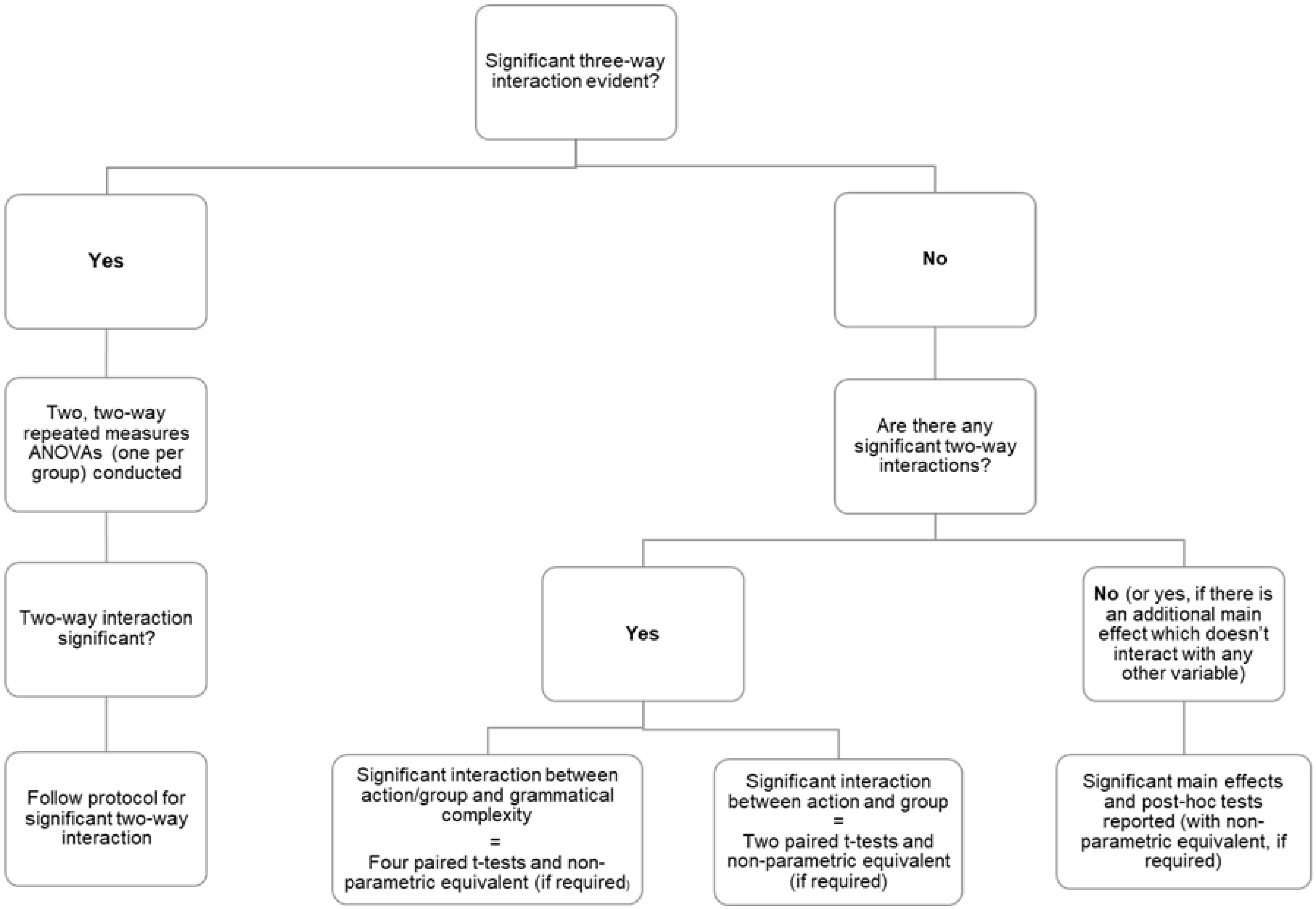


Figure 2. Protocol for significant interactions and main effects.

In all instances (including for any ANOVAs), the fact of whether the data met the necessary assumptions for parametric testing was established using the following tests. To test the assumption of normal distribution, Shapiro-Wilk tests were utilised ($p < .05$ used to indicate violation). Levene's tests were meanwhile used to test the homogeneity of variance ($p < .05$ used to indicate violation) and Box's M Tests to test the homogeneity of covariances ($p < .001$ used to indicate violation). The presence of outliers was assessed using the following protocol. For any ANOVA, significant outliers were considered to be any residuals with a value greater than +/- 3. For all two group comparisons (whether that be between or within group) the boxplot procedure was used, with a multiplier of 3 (i.e., outliers were considered to be any values greater than 3 times the interquartile range). It was planned that outliers would not be excluded from the data *unless* there was an identifiable reason for their presence. In any instances where this occurred, the reasoning for it has been outlined within the relevant section.

Regression was considered for the correlational analysis, however was considered inappropriate given the number of independent variables under consideration in relation to the sample size. Correlation was consequently conducted to yield the tentative pattern of relationships amongst variables. Whilst this cannot provide as much information regarding the relationship between the variables, it serves as a good indicator of where/whether relationships exist between variables and thus can assist in guiding the focus of future investigations.

2.5.5 Effect Size Calculation

Effect sizes for paired and independent sample comparisons were calculated as follows. For parametric calculations (i.e., in instances in which the data met the assumption for parametric analysis), effect size (Cohen's *d)* was calculated using

ESCI (Exploratory Software for Confidence Intervals); developed by Geoff Cummings and downloaded from: https://thenewstatistics.com/itns/esci/). Effect size for non-parametric analyses was calculated using ‘normal approximation *z* to *r*’ (Wuensch, 2015) when the standardised test statistic (z) is divided by the square root of the number of pairs (z/√n pairs). Effect sizes (partial eta-squared; η_p^2) for any reported mixed factorial ANOVAs were calculated using SPSS.

2.5.6 Plots

All plots, unless otherwise specified, were created in Microsoft Excel using a template developed by Weissgerber, Milic, Winham, and Garovic (2015). Where required, these templates were adapted as necessary for the intended purpose.

2.6 Summary

This chapter has provided an overview of the overall design and structure of the research, and the tasks utilised within it. In the following chapters, a detailed description of the designs and procedures adopted to explore each research question is presented, followed by the relevant results and a discussion of the findings, in relation to the hypotheses made.

3 General Linguistic and Cognitive Profile

3.1 Introduction

This profile was designed to provide a general understanding of cognitive and linguistic processing in each experimental group (individuals with Parkinson's Disease [PD] and neurotypical control participants) and formed the foundation within which results relating to the specific research questions was considered. As illustrated in Figure 3, performance in nine primary functional areas was measured. In some instances, for example with speech initiation, the information gleaned was used to assess whether adjustment needed to be made in the scoring of the experimental tasks, to ensure any finding was reflective of the process under investigation and did not involve a confounding variable. For others, measures were included in correlational analyses.

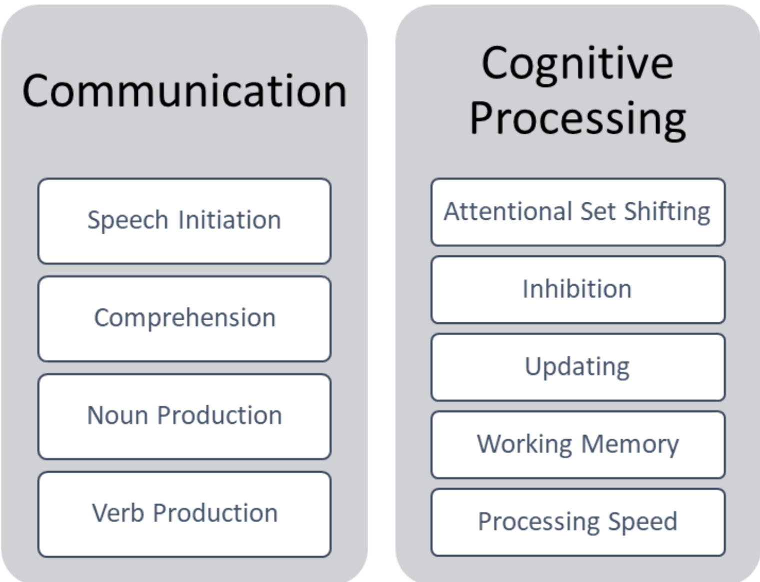


Figure 3. Processing explored to form the general linguistic and cognitive profile

The materials utilised within the tasks corresponding to each domain outlined are fully detailed in the following section (Section 3.2). This is followed by the results of the analyses (Section 3.3), which are then drawn together in a discussion of the findings (Section 3.4).

3.2 Method

As part of the aim to gain a general understanding of cognitive and linguistic performance in each experimental group, performance in each quantitative measure was compared between groups. In some tasks, a further variable was necessarily manipulated in order to understand the linguistic or cognitive process under investigation. In these instances, a mixed factorial design was adopted to explore how the processing of the stimuli under investigation varied between groups.

3.2.1 Speech Initiation

A non-word production task was developed to assess speech initiation between groups. Verbal response time (RT) was a dependent variable within many of the experimental tasks used within this study, and it is known that speech movement initiation can be affected by PD (Ramig, Fox, & Sapir, 2008). To avoid any effect of group being skewed by a general difference in speech initiation time, a speech initiation task was carried out, to establish if any significant difference in initiation time existed between groups.

Materials

Consonant-vowel (CV) nonsense words were created through combining each of the consonants which can allowably appear at the start of a word in English with three of the corner vowels: /i/, /u/ and /a/ (represented orthographically as ‘ee’, ‘ooh’ and ‘ah’ respectively). The subsequent list of 63 nonsense words can be found in

Appendix H. Each stimulus was written in ‘Courier New’ font, size ‘30’, and displayed via a laptop.

Procedure and Scoring

The 63 stimuli, divided across two task blocks (the first containing 31 trials and the second 32 trials), were shown to participants one at a time (see Figure 4). Participants were asked to say the nonsense word shown on the screen aloud as soon as they could upon seeing it.

RT for each stimulus was calculated using the procedure detailed in Section 2.3.3. Individuals’ first answer was taken, in the small number of occasions where individuals altered their pronunciation. A mean RT was then calculated for each individual, by dividing the sum of all RTs by the number of stimuli. This served as their RT score.

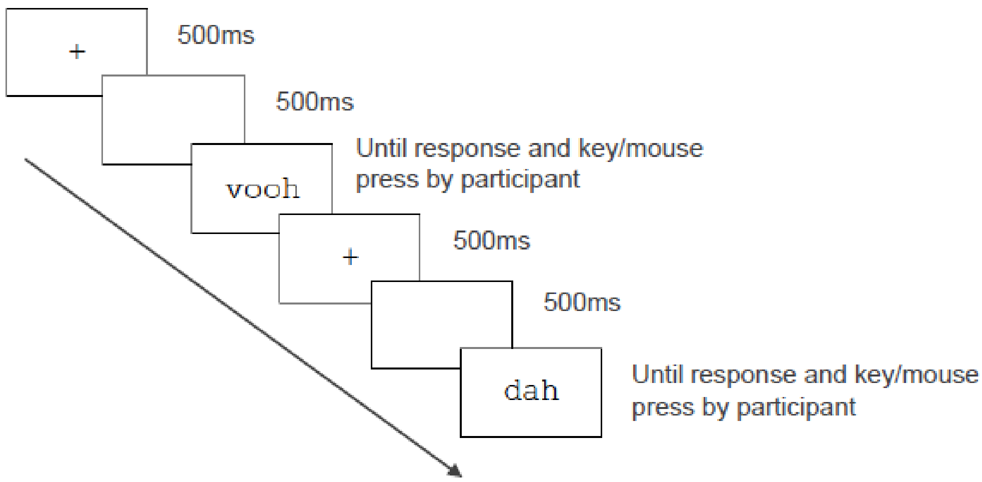


Figure 4. Speech Initiation Task procedure

3.2.2 Sentence Comprehension

Sentence comprehension was assessed using two tasks from the Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan, & Barresi, 2001). The suitability of aphasia batteries to assess language functioning in PD has been questioned (Miller, 2012, 2017) however there is evidence to suggest that the aforementioned comprehension subtests specifically are sensitive to PD, including in the early stages (Bocanegra et al., 2015; García et al., 2017 - see also Baez et al., 2020 for discussion). Given their indicated suitability for use with a mixed group of individuals with PD (i.e., who were not sub-typed according to disease progression, for example) in a research context, and their ability to provide a measure of two different aspects of syntactic processing (functional-role assignment and the processing of embedded clauses), they were considered appropriate for utilisation within this study.

Materials

As just outlined, two subtests from the BDAE were run, the first requiring the processing of multiple elements (e.g., '[show me in which picture is the person…] with the comb, touching the knife') and the second the processing of embedded clauses (e.g., 'the boy wearing a hat kicks the girl'). For both subtests, materials consisted of printed sheets, each containing four line drawings depicting a slightly different scenario. In the 'Touching A with B' subtest, each picture depicted a hand either holding or touching an object. In the 'Embedded Sentences' subtest, two characters, interacting in various ways, were depicted. A list of sentences to be read aloud by the examiner were provided; one per sheet of four pictures.

Procedure and Scoring

The task was delivered as per the instructions outlined within the assessment manual. In front of the participant, the sheet showing four pictures (one per quarter) was placed. The researcher then read aloud a sentence and each participant was asked to indicate which picture, from the four visible in front of them, corresponded with the sentence that they had just been heard. The subtests were run in the same order for all participants, with the ‘Touching A with B’ subtest completed first. The ‘Touching A with B’ subtest consisted of 12 trials, and the ‘Embedded Sentences’ subtest of 10 trials.

Responses were marked as correct if an individual pointed to the target picture, following the sentence reading. Corrected answers were accepted. Correct answers were given 1 point, and incorrect answers given 0. An accuracy score was collated for each subtest, as well as an overall comprehension score calculated through combining the scores from both subtests.

3.2.3 Noun Naming

An object, picture naming test was developed to assess noun production in PD at a single word level. Picture naming is a common and well established means through which to assess word retrieval and has been used in a number of previous studies exploring lexical processing in PD (e.g., Cotelli et al., 2007).

Materials

A target list of 42 nouns (see Appendix I for the full word list), divided into three groups according to the level of motion association with the noun’s meaning, was devised. This comprised 14 nouns with a high level of associated motion/movement (i.e., animate objects, such as ‘dog’), 14 nouns with some associated motion/movement (i.e., objects which move or are physically moved as part of their function, e.g., ‘axe’) and 14 nouns with no obvious associated motion/movement associated (i.e., objects which do not or are not physically moved as part of their function, e.g., ‘table’).

Nouns within each condition were matched[11] for frequency, $\chi^2(2) = 0.94$, $p = .954$, age of acquisition (AoA), $\chi^2(2) = 0.68$, $p = .712$, concreteness, $\chi^2(2) = 1.99$, $p = .369$, length, $\chi^2(2) = 0.21$, $p = .940$, and orthographic, $\chi^2(2) = 0.45$, $p = .799$, and phonological (excluding homophones) neighbours, $\chi^2(2) = 0.13$, $p = .936$. Forty-two corresponding picture stimuli were created, depicting each target noun. These stimuli, scaled to approximately 550 x 367 pixels (appearing as approximately 11.1cm x 7.4cm), were matched for visual complexity, $F(2, 41) = 1.71$, $p = .113$. All stimuli were presented via a laptop.

Procedure and Scoring

Participants were asked to name the object shown in the picture as soon as they could, using one word. The task was conducted according to the procedure illustrated in Figure 4, with stimuli delivered over two equal task blocks. An example picture stimulus is provided in Figure 5.

[11] See Section 2.3.1 for full detail of the procedures followed

High Motion	Some Motion	No Motion

Figure 5. Example stimuli used within the noun naming task.

Responses were marked as correct if the target noun had been used. One point was given to correct answers and zero points awarded to incorrect answers. Corrected answers (i.e., corrections made immediately after an initial answer had been given) were accepted. The sum of each individual’s points formed their score. In readiness for comparison with performance in the verb naming task, a percentage correct score was additionally calculated by dividing each participant’s score by the number of stimuli (i.e., the total possible score) and multiplying that figure by 100. RT was calculated according to the protocol outlined in Section 2.3.3, with the following rules applied:

- If any individual was still speaking from the previous stimuli when the beep was heard, RT was calculated as the time between the end of their previous utterance and their next answer, plus the length of the beep.
- If an individual made any comment past the beep that was not relating to the stimuli in front of them, the length of this comment was deducted from the RT.

RT was only calculated for correct (*not* including corrected) answers and the consequent data trimmed using an absolute cut-off. In line with previous studies investigating executive and lexical processing in PD (Cools et al., 2001b; Silveri et al., 2018) any response found to be >5000ms was excluded from the analysis (representing 12 responses, or 0.82% of all correct responses). Responses <250ms was similarly identified for removal (in reality, no responses were removed under this criteria). A mean RT score per participant, per condition, was then calculated.

3.2.4 Verb Naming

One multi-purpose verb naming task was employed within the study, designed – through the implementation of different levels of analysis – to provide both a measure of verb processing generally and a measure of the processing of verbs with particular action meaning and grammatical characteristics. First, responses from the task were used to explore whether a selective verb deficit was evident in PD, achieved through comparing overall performance in this task with that in the noun naming task.

Materials

A list of 56 verbs (see Appendix J for the full word list) and corresponding picture stimuli was developed. In all corresponding picture stimuli, a person was depicted carrying out the action. If there was any ambiguity as to which person was carrying out the action of interest, an arrow was inserted into the picture to make this clear. All pictures were scaled to approximately 550 x 367 pixels (appearing as approximately 11.1cm x 7.4cm).

The verb and noun word lists were matched[11] for word frequency, $U = 1240$, $p = .646$, AoA, $U = 1063$, $p = .417$, word length, $U = 1282$, $p = .439$ and the number of orthographic, $U = 1037$, $p = .308$, and phonological neighbours, $U = 974$, $p = .142$.

As might be expected, concreteness scores were significantly higher in the noun than the verb condition, $U = 2342$, $p < .001$. Due to the restrictions placed on verb selection (see Section 4.2.1), it was not possible to alter the target word lists to rectify this. The potential effect of this difference in concreteness was, however, taken into account when considering findings. The picture stimuli for each word class were matched for visual complexity, $U = 1124$, $p = .709$.

Procedure and Scoring

This task was run and scored exactly as per the previous noun naming task (see Section 3.2.3) with, in this instance, participants asked to name the depicted action. Targets presented in a phrase (e.g., ‘unlocking the padlock’ were accepted as correct. For each participant, a percentage correct score was calculated. RT was calculated according to the protocol outlined in Section 3.2.3. Thirty one responses (2.22% of total correct responses) were excluded due to being >5000ms.

3.2.5 Cognitive Processing

The cognitive task battery was designed to tap into five core cognitive domains: the three separable aspects of executive functioning (set shifting, inhibition, and working memory updating), short term and verbal working memory (storage, plus processing and storage) and processing speed; all processes shown to be vulnerable in PD and previously explored in some form in relation to language processing alteration in PD (see Section 1.2.3.3 and 1.2.4.1). This battery does not cover all five cognitive domains[12] suggested by Litvan et al. (2011) for comprehensive assessment. However, the number of tasks administered had to be constrained in view of the assessment load on participants, and priority was therefore given to the cognitive domains previously considered within the literature in relation to language processing: executive functioning and short term and working memory. Further, both memory recall and visuospatial functioning are assessed within the M-ACE, enabling a degree of understanding of functioning within those domains to be established (see Section 2.2.5).

Task impurity can be a particular problem in tasks investigating executive functioning given the fact that, by their very nature, executive functions control other cognitive processes (Friedman & Miyake, 2017; Miyake & Friedman, 2012). With regard to language processing, whether the executive control processes employed are domain-specific or domain-general remains a matter of debate and continued exploration (Bourguignon & Gracco, 2019; Thompson-Schill et al., 2005; Ye & Zhou, 2009). A design within which multiple tasks were included for each executive function of interest could have been elucidating in this regard (see also Bourguignon & Gracco, 2019 for useful discussion regarding the existence of a single central 'controller'). This approach could have varied the cognitive process being controlled, similarly to the latent variable approach suggested by Miyake and Friedman (2012 – see also Friedman & Miyake, 2017; Miyake, Friedman, et al., 2000). It was not, however, feasible to include such a design within this study, again due to the number of other tasks already being employed. As such, the decision was taken to select tasks which gave as 'pure' a measure of the executive function of interest as possible, through limiting the confounding influence of other cognitive processes.

Utilising tasks relying heavily on lexical processing would have made it difficult to tease apart whether any potential difference in performance in PD was a reflection of altered executive control processing (which could be either domain general or domain specific) or another aspect of lexical processing (such as degraded conceptual representations, for example) and introduced a confound when considering the relationship between performance within the language and executive functioning tasks. Removing this confound from the correlational analysis was considered to be particularly important. Whilst limited conclusions can be drawn from such analysis, were any relationship to be indicated between any of the executive and language measures of interest, this could provide useful information regarding the general/specific nature of the executive processes employed during language processing. Thus, on balance it was felt that, within the constraints being worked in, it was pertinent to concentrate on executive tasks designed to minimise the confounding influence of other cognitive processes, including language. The tasks employed were considered to meet that brief.

3.2.5.1 (Attentional) Set Shifting

This task was based on a protocol developed by Cools et al. (2001b), previously used successfully with individuals with PD. The task taps attentional set shifting such that, whilst the stimuli were reconfigured, the required response remained the same (Sawada, Nishio, Suzuki, & Hirayama, 2012).

Materials

Stimuli consisted of 80 number and letter pairs, comprising a random combination of the letters ‘K’, ‘N’, ‘R’, ‘F’ and ‘Y’ and the numbers ‘2’, ‘3’, ‘4’, ‘5’ and ‘6’. Each possible number and letter combination, in both letter and number first formations (e.g., K2, 2K, K3, 3K etc.) were compiled, and randomised using Microsoft Excel. The first 40 pairs from that randomised list became the first 40 stimuli. This process was then repeated to create the remaining 40 stimuli. The full list of stimuli, in presentation order, can be found in Appendix L. Stimuli were shown via the laptop, on a coloured rectangle measuring 20.7cm x 11.65cm. The colour of the rectangle varied between trials.

Procedure and Scoring

Participants were shown each stimulus in turn and asked to name either the letter or the number observable in the pair, according to the colour of the rectangular background. Half the participants were instructed to say aloud the name of the letter if the background was green and the name of the number if the background was red, whilst the other half of the participants received the reverse instructions. Mann Whitney U tests confirmed the lack of any significant effect of instruction (i.e., the number/letter-colour pairing) on either the accuracy or RT measures (all $p > .26$).

A prompt sheet was placed in front of each individual to remind them of these instructions. The background colour changed for every other stimulus (thus a shift was required on every other response), with all participants starting with a green background. Individuals were asked to give their answer as soon as they could following the presentation of each stimulus. Stimuli were presented across two, equal task blocks. A full illustration of the task procedure can be found in Figure 6.

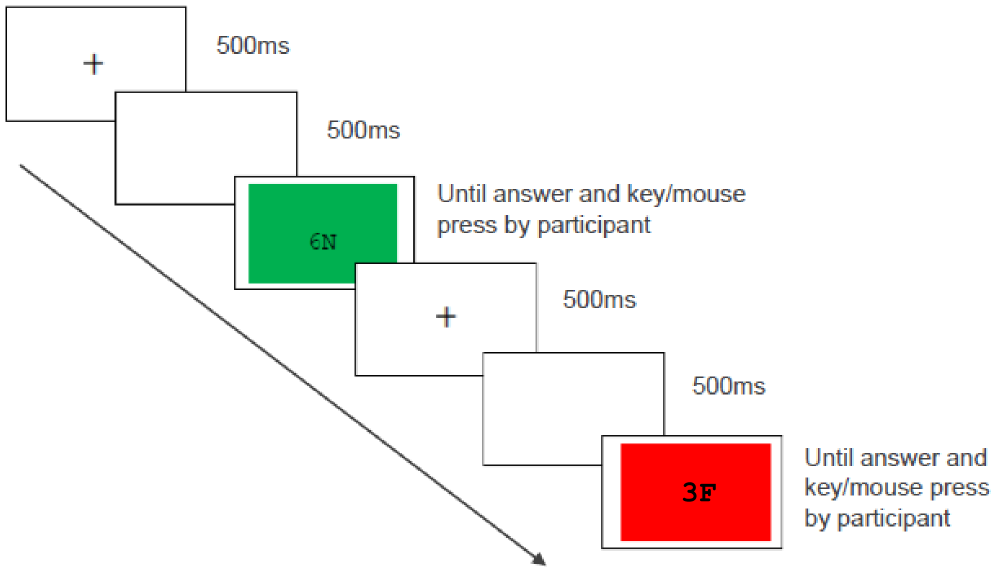


Figure 6. Procedure for the Set Shifting Task (switch condition)

Answers were marked as correct if they matched the target specified by the colour of the background. All mistakes were counted as errors, even if corrected, and it was this error tally which formed the dependent variable in subsequent analysis. Any errors which did not relate to the condition (for example, if an individual named the number when number was the target but said an incorrect number) were excluded from this tally, to ensure this was an accurate measure of shift cost. RT was calculated following the protocol outlined in the noun naming task (see Section 3.2.3). In total, five responses >5000ms were removed from the RT data (0.16% of all correct responses).

3.2.5.2 Inhibition

To assess inhibition, a computerised version of the Stroop task, based on Miyake et al. (2000) was utilised.

Materials

A list of 126 stimuli was formulated, divided into 15 congruent stimuli (the 'ink' colour matched the colour word), 48 incongruent stimuli (the 'ink' colour differed from the written colour word) and 63 control trials (48 control, non-colour words and 15 symbols (#) written in coloured 'ink'). The congruent condition was included to enable any semantic boost effect to be investigated, through considering performance in the congruent condition in relation to the control condition. By including two forms of control stimuli (control words and symbols), it was further possible to investigate the level of distraction provided by each of these neutral conditions in the PD group, as compared with controls.

The four colours used were red, green, purple, and yellow and the four unrelated control words were *'old'*, *'quick'*, *'clever'* and *'lively'*. These control and colour words were matched for word type (all words were adjectives), frequency, $t(6) = 0.11$, $p =$

.913, and length, with one three letter word, two five letter words and one six letter word per group. The full list of stimuli, presented via a laptop, and the colour ink in which they appeared can be found in Appendix M. Following randomisation, if there were any examples of two word/symbols appearing consecutively in the same colour ink, the second of the two words was swapped with the nearest stimuli of the same type (e.g., an incongruent trial was swapped with the nearest other incongruent trial).

Procedure and Scoring

A mixed trial-block procedure was adopted (see Appendix M for presentation order per block). Participants were shown a stimulus and asked to name the colour the word or symbol was printed in, as quickly as possible. A detailed illustration of the paradigm is provided in Figure 7. Stimuli were presented across three equal blocks, each containing 16 incongruent trials (a colour word printed in a different colour ink), 21 control trials (16 unrelated words printed in a coloured ink, and five '#' symbols printed in coloured ink) and five congruent trials (a colour word printed in the same colour ink).

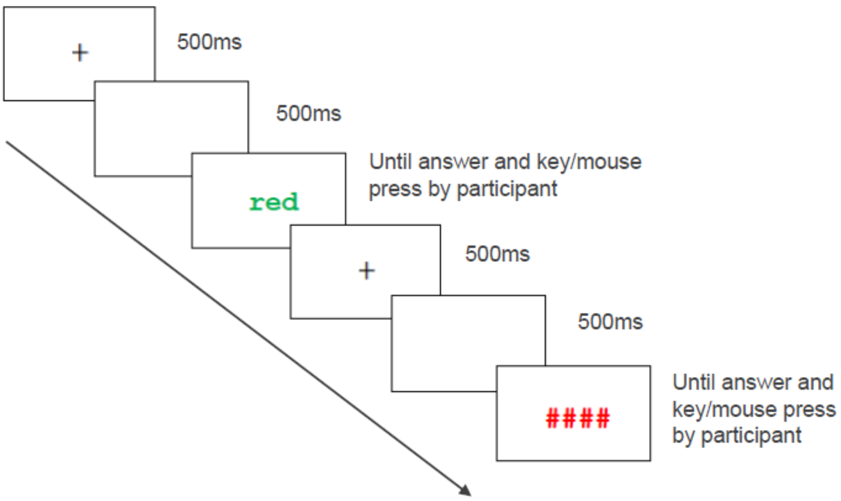


Figure 7. Procedure for the Stroop Task

RT was calculated using the same protocol outlined in Section 3.2.3. No responses exceeded 5000ms. The difference in the time taken for participants to respond to incongruent trials and control trials (word stimuli only) was taken as their inhibitory cost score.

3.2.5.3 Working Memory Updating

A verbal n-back task was chosen to investigate working memory updating, having been successfully utilised with individuals with PD (Marklund et al., 2009), aphasia (Christensen & Wright, 2010) and older adults (Hull, Martin, Beier, Lane, & Hamilton, 2008). Within the task, individuals are shown a list of items and are required to decide whether the item shown on the screen is the same or different to that seen *n* items earlier. A two-back task, based on a protocol developed by Marklund et al. (2009) was chosen, thus involving both ‘shift’ (i.e., upon presentation of a new item, the item that was in first position in the remembered list needed to be shifted into the second position) and ‘replacement’ (i.e., upon presentation of a new item, that new item needed to replace the item previously in first position; Chen, Mitra, & Schlaghecken, 2008).

Materials

Stimuli for the task consisted of four word lists, each containing eight words. The words used in the lists were ‘pot’, ‘arm’ and ‘kid’, chosen due to their similar word characteristics (frequency ranged from 4.7-4.78, concreteness from 4.56-4.96) and equal word length, but limited semantic association. The words were arranged in the lists such that three of the words were targets (i.e., they were the same as the word two words back in the list) and three were foils, e.g., ‘pot, arm, **pot**, kid, arm, **kid, arm,** pot’. A range of possible foil/target patterns were created from which the four used patterns were chosen, with the aim being that they were maximally distinctive. Stimuli were presented via the laptop. For the full list of stimuli, see Appendix N.

Procedure and Scoring

Participants were shown each word in turn, and asked to say aloud, as soon as they could, whether the word on the screen was the same, or different, to that which had been presented two words earlier. The task was paced, with each stimulus shown on the screen for a set length of time (1000ms), followed by a timed inter-stimulus interval (ISI). In the first two blocks (the first two word lists), this ISI was set at 6000ms, and in the final two blocks at 3000ms. See Figure 8 for a full illustration of the procedure. Due to the complexity of the task, four practice blocks (word lists) were prepared, and individuals were encouraged to complete as many blocks as required to become accustomed to the task.

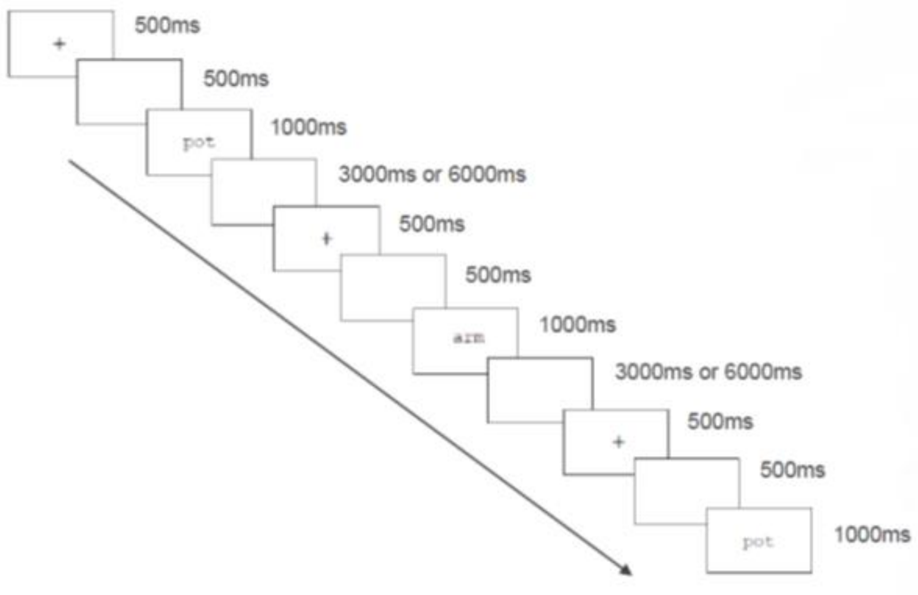


Figure 8. Procedure for the Updating task

Answers were scored according to whether they were correct or incorrect. Correct scores were given a score of 1 and summed to create participants' overall score, per condition. Corrected answers were accepted. RT was calculated using the method outlined in Section 3.2.3. Four responses exceeded 5000ms (0.46% of total correct responses) and were consequently removed from the dataset.

3.2.5.4 Short Term and Working Memory

Forward and backward digit span was used to assess short term memory capacity and the ability both to store and manipulate information in working memory, respectively (Monaco, Costa, Caltagirone, & Carlesimo, 2013; see also Logie, 2011, for general discussion regarding the organisation of working memory).

Materials

Stimuli for the tasks consisted of 27 number sequences, ranging from two to nine digits in length. Three sequences for each digit length were created (leading to 27 lists in total), using Research Randomizer (https://www.randomizer.org/). Each sequence used the numbers 1-9, with each possible number appearing only once within a sequence (i.e., the nine digit lists contained all possible numbers). The list of stimuli for both the forwards and backwards digit span can be found in Appendix O.

Procedure and Scoring

Starting from the shortest digit sequence length (2), sequences were read aloud to participants, who were asked to repeat them back either in the same (forwards span) or reverse (backwards span) order. A blocked procedure was implemented, such that all forward trials were conducted prior to commencement of the backwards trials. If individuals correctly repeated back at least one of the three number sequences within a given digit length, they moved on to the next sequence length. Testing ceased either when the maximum digit length (9) had been reached, or participants were not able to recall any sequences of a given digit length correctly.

Each individual's digit span was devised by averaging the length of the last three sequences correctly recalled, which is more sensitive than scoring according to the maximum sequence length achieved (e.g., Brown, 2016). For example, if a participant got all three of the sequences containing five numbers correct, two of the sequences containing six numbers correct but none of the sets containing seven numbers correct, their score would be (6+6+5)/3 (equalling 5.67). A measure of processing cost was additionally calculated by deducting scores in the backward condition from the forward condition.

3.2.5.5 Processing Speed

A difficulty with many processing speed tasks is their reliance on the speed of motor movement. To avoid this, a visual inspection time task was chosen for this study, based on the protocol utilised by Pettit et al. (2013) and Johnson et al. (2004). Here, processing speed is a measure of the time within which individuals are able to process the characteristics of the given stimuli, shorn of their speed of manual response. Tasks of this type have been successfully used with individuals with PD (Johnson et al., 2004) and motor neurone disease (Pettit et al., 2013), and used widely with older adults (e.g., Deary et al., 2007).

Materials

The stimulus consisted of a pi figure (see Figure 9) which was created using Microsoft Publisher and Microsoft Paint. The figure appeared as 2.9cm across, with the short side measuring 1.45cm and the long side measuring 2.9cm. The stimuli were displayed at up to eight different durations: 150ms, 125ms, 102ms, 85ms, 68ms, 51ms, 34ms and 17ms. For each presentation duration, a sequence of six ‘pi’ figures were created, consisting of six randomly ordered pi figures, half of which had longer left sides and half longer right sides. The order of these pi figure sequences, for each duration, are provided in Appendix P.

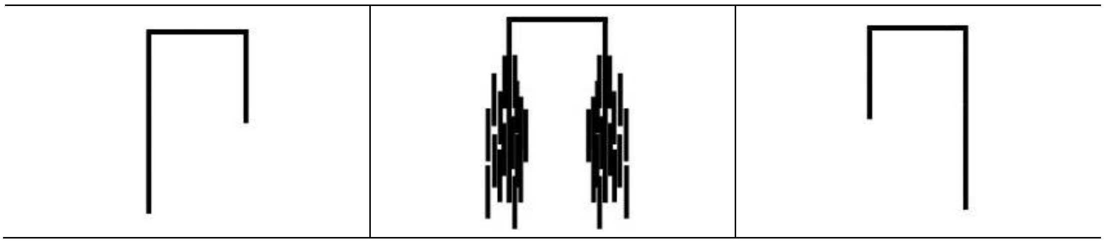


Figure 9. Illustration of the left side longer, masked, and right side longer Pi figures utilised within the visual inspection time task

Procedure and Scoring

Stimuli were delivered across eight task blocks, one per duration condition. Within each block, the Pi figure was displayed on the screen for the set duration before being replaced by the mask to prevent further processing (see Figure 10). Duration became shorter as the blocks progressed, with participants moving on to the next block only if they scored 5 or more (out of a possible 6) in the current block. Participants were asked to say aloud which side of the ‘pi’ figure they had seen was longer. It was stressed that individuals could answer in their own time. A left and right reminder marker was provided for individuals in front of the laptop screen.

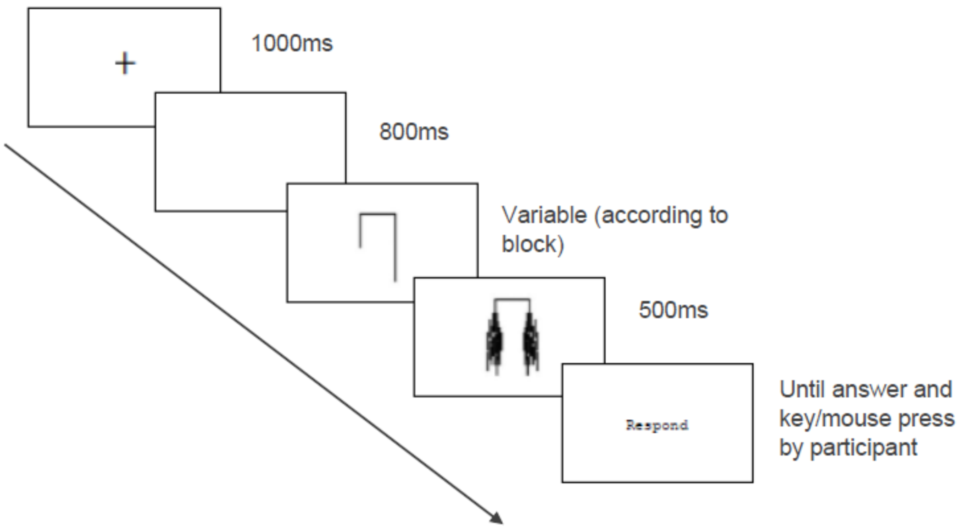


Figure 10. Procedure for the Visual Inspection Time Task

Answers were marked as correct if the participant had correctly identified which side of the shape was longer. The last block at which individuals had scored five or more was taken as their processing speed score.

3.3 Results

3.3.1 Speech Initiation

An independent t-test was conducted to establish whether a significant difference in speech initiation existed between the two groups. The analysis revealed no significant effect of group, $t(39) = 1.35$, $p = .186$, $d = 0.43$, with the data distribution similar across groups ($M_{PD} = 663$, $SD_{PD} = 192$; $M_{Control} = 594$, $SD_{Control} = 139$). Because no difference in speech initiation between the groups was indicated, it was not felt necessary to control for speech initiation in RT measures in subsequent tasks.

3.3.2 Sentence Comprehension

Mann-Whitney U tests (chosen due to non-normality in the data) were run to compare performance in each comprehension subtest between groups. Mean and mean ranked scores per subtest, according to group, are presented in Table 5.

Table 5.

Mean (SD) and Median (IQR) comprehension scores per subtest, according to group

	PD	Control
	Mean (SD) *Mean ranked score*	Mean (SD) *Mean ranked score*
Touching A with B	11.1 (1.61) *20.5*	11.3 (1.10) *21.3*
Embedded Sentences	9.75 (0.45) *18.4*	9.96 (0.20) *22.7*
Comprehension Total	20.8 (1.83) *19.8*	21.2 (1.19) *21.8*

A significant difference in performance was evident in the ‘Embedded Sentences’ subtask, $U = 242$, $p = .048$, $r = 0.31$, with scores lower in the PD group ($Mean\ ranked\ score_{PD} = 18.4$, $Mean\ ranked\ score_{Control} = 22.7$). No other comparisons were significant (all $p > .55$). Inspection of the data indicated that a subgroup of individuals experienced difficulties (4 individuals with PD, and one control), with the remainder performing at ceiling (see Figure 11).

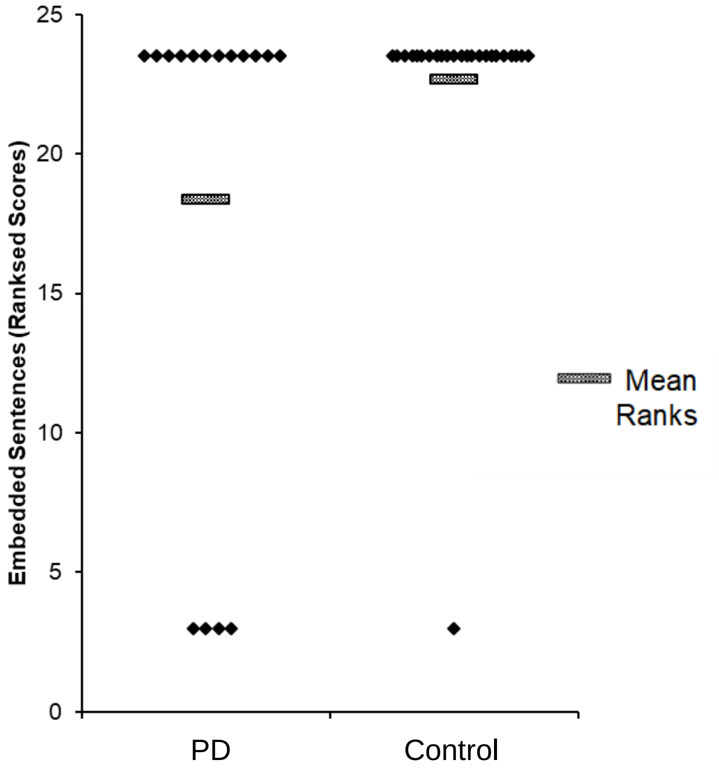


Figure 11. Distribution of ranked accuracy scores in the embedded sentences subtest, as a function of group

Further consideration of the data did not point to any obvious classifying features of the PD subgroup; years of education and gender were mixed, and the time (in years) since diagnosis varied.

3.3.3 Noun Production

Accuracy and RT were each analysed using a 2 (group) x 3 (associated motion) mixed factorial ANOVA. The data can be found in Table 6 below.

Table 6.

Mean (SD) and median (IQR) accuracy and RT (ms) scores in the noun naming task, as a function of group and motion

		PD	Control
		Mean (SD)	Mean (SD)
		Median (IQR)	*Median (IQR)*
Accuracy	High Motion	12.3 (1.34)	12.5 (0.96)
		12.0 (2.00)	*12.0 (1.00)*
	Some Motion	12.3 (1.45)	12.5 (0.96)
		12.5 (3.00)	*12.0 (1.00)*
	Low Motion	11.4 (1.26)	11.7 (1.17)
		11.0 (3.00)	*12.0 (2.00)*
RT (ms)	High Motion	1132 (234)	1043 (170)
		1030 (374)	*1017 (256)*
	Some Motion	1130 (223)	1031 (213)
		1063 (241)	*982 (339)*
	Low Motion	1176 (235)	1070 (171)
		1155 (339)	*1033 (271)*

Analysis indicated a significant main effect of noun type on accuracy, $F(2,78) = 7.40$, $MSE = 1.25$, $p = .001$, $\eta_p^2 = .16$. There was no significant main effect of group or interaction between the variables (all $p \geq .27$). Collapsed across group, post-hoc analysis ($\alpha = .05$)[10] revealed accuracy scores in the no motion group (*estimated marginal mean [EMM]* = 11.5, *SE* = 0.19) to be significantly lower than those in the high motion (*EMM* = 12.4, *SE* = 0.18; $p = .006$) and some motion (*EMM* = 12.4, *SE* = 0.19; $p = .006$) conditions. All other comparisons were non-significant (all p = 1.00).

Data for the ANOVA failed the assumption of normality and the assumptions of the analysis signalling a significant main effect of motion consequently checked (see Section 2.5.4 for a reminder of the protocol followed). The data contained a significant outlier and failed the assumption of normality, and a non-parametric Friedman test consequently conducted. Findings from this test supported the presence of a main effect of motion, $\chi^2(2) = 9.65$, $p = .008$, with Dunn's pairwise comparisons ($\alpha = .05$)[10] corroborating presence of a significant difference between scores in the high and low motion condition, $p = .020$. All other comparisons were non-significant (all $p \geq .10$). Thus, whilst motion appears to have a facilitatory effect on noun naming, the significance of its influence on nouns containing some action needs to be interpreted with caution.

When considering RT, there was no significant main effect of either group, $F(1, 39) = 2.84$, $MSE = 99259$, $p = .100$, $\eta_p^2 = .068$, or motion content, $F(2, 78) = 1.55$, $MSE = 12954$, $p = .219$, $\eta_p^2 = .038$, and no significant interaction existed between the variables, $F(2, 78) = 0.60$, $MSE = 12954$, $p = .942$, $\eta_p^2 = .002$.

Examination of the raw data highlighted that a greater variability of responses was evident in response to some stimuli than to others. To address the potential that this stimulus-led variability may be confounding the results (in other words, that the reliability of the picture to elicit the target response may be influencing findings), the following protocol – adapted from that reported by Cycowicz, Friedman, Rothstein, and Snodgrass (1997) – was conducted. The answers given in response to each stimulus by the control participants ($n = 25$) were examined and the modal response (i.e., the response which occurred most frequently) for each stimulus calculated. Any stimulus for which the modal response was *not* the target was then removed from the dataset, and the analysis re-run on this adjusted dataset.

In the case of noun naming, only one stimulus fell into this category: ‘baboon’. Because this removal resulted in the number of stimuli within each experimental level being uneven, noun naming accuracy was reassessed using percentage correct, rather than the total score.

For both accuracy and RT, findings from the analysis run on the adjusted dataset mirrored those previously seen. For accuracy, a significant main effect of motion was shown, $F(2, 78) = 17.7$, $MSE = 59.3$, $p < .001$, $\eta_p^2 = .31$, with post-hoc analysis ($\alpha = .05$)[10] indicating scores in the no motion condition (*EMM* = 82.5, *SE* = 1.38) to be significantly lower than those in both the some (*EMM* = 88.7, *SE* = 1.34) and high motion (*EMM* = 92.8, *SE* = 1.19) conditions (in all other comparisons, $p > .05$). Again, whilst the difference between the no motion and high motion (animate) nouns was corroborated by non-parametric analysis ($p = .003$) the difference between scores in the no and some motion condition was not supported ($p = .408$). For RT, no main effects or interactions were significant (all $p > .090$).

Summary of Results

Collapsed across groups, a significant effect of associated motion was evident on noun production accuracy. Specifically, nouns with no associated motion were shown to be produced significantly less accurately than those with a high level of motion associated with their meaning. Whilst findings from the ANOVA additionally indicated a significant difference in accuracy to exist between nouns containing no and some associated motion, the existence of such a difference was not supported by non-parametric analysis. The pattern seen within the accuracy data did not extend to RT, with no significant effect of either associated motion or group – or interaction between the two – evident.

3.3.4 Verb and Noun Production

A 2 (group) x 2 (word class) mixed factorial ANOVA was conducted to assess the influence of word class (noun vs verb) on both accuracy and RT in turn. The data are presented in Table 7.

Table 7.

Mean (SD) and median (IQR) accuracy and RT (ms) scores, as a function of group and word class

		PD	Control
		Mean (SD)	Mean (SD)
		Median (IQR)	*Median (IQR)*
Accuracy (% correct)	Noun	85.6 (6.53)	87.4 (4.15)
		88.1 (11.3)	*88.1 (5.95)*
	Verb	59.0 (9.73)	63.6 (8.34)
		60.7 (12.5)	*62.5 (10.7)*
RT (ms)	Noun	1148 (206)	1048 (166)
		1080 (307)	*1033 (151)*
	Verb	1736 (388)	1567 (301)
		1680 (772)	*1554 (386)*

Findings relating to accuracy are presented first. A significant main effect of word class was evident, $F(1,39) = 399$, $MSE = 30.9$, $p < .001$, $\eta_p^2 = .91$. Collapsing across groups, greater accuracy was seen in the noun naming condition ($EMM_{Verb} = 61.3$, $SE_{Verb} = 1.43$; $EMM_{Noun} = 86.5$, $SE_{Noun} = 0.83$). As illustrated in Figure 12, this pattern was shown by all participants, suggesting a uniform processing advantage for nouns. There was no significant main effect of group present, $F(1,39) = 2.71$, $MSE = 75.3$, $p = .108$, $\eta_p^2 = .065$,or interaction between variables, $F(1,39) = 1.18$, $MSE = 30.9$, $p = .283$, $\eta_p^2 = .029$.

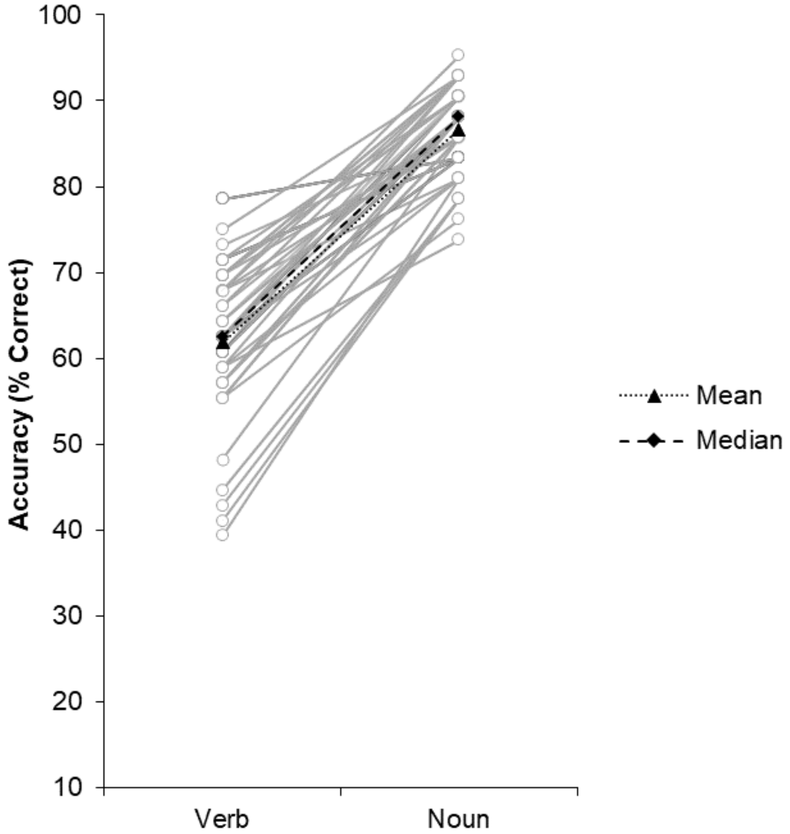


Figure 12. Illustration of the significant main effect of word class on production accuracy, per participant

Data for the ANOVA failed the assumption of normality and homogeneity however because data for the within-subjects (word class) comparison met the necessary assumptions of parametric analysis, there was no need for further analysis.

For RT, the pattern of results reflected that seen for response accuracy. Analysis revealed a significant main effect of word class, $F(1,39) = 144$, $MSE = 41460$, $p < .001$, $\eta_p^2 = .79$. Collapsing across groups, stimuli were responded to significantly faster in the noun condition ($EMM_{Verb} = 1652$ms, $SE_{Verb} = 54.0$ms; $EMM_{Noun} = 1098$ms, $SE_{Noun} = 29.1$ms), a pattern once again shown by all participants. No main effect of group, $F(1,39) = 3.34$, $MSE = 105556$, $p = .075$, $\eta_p^2 = .079$ or significant interaction, $F(1,39) = 0.58$, $MSE = 41460$, $p = .452$, $\eta_p^2 = .015$, was present.

RT data again failed the assumption of normality. This assumption was also violated in the data for the within-subjects comparison, and a non-parametric Sign test consequently conducted to validate findings. Findings supported the presence of a significant effect of word type, $z = -6.25$, $p < .001$, $r = 0.98$.

To investigate whether stimulus-led variability may be confounding the results, the same process was conducted as outlined in the previous task (Section 3.2.3) and the analysis rerun on the adjusted data set. The same one stimulus – 'baboon', was removed from the noun level of the 'word type' factor, and ten from the verb level ('bury', 'chat', 'collide', 'sob', 'sprinkle', 'stumble', 'swallow', 'tiptoe', 'unload' and 'unlock'). Once again, findings from the adjusted dataset, both for accuracy and RT, mirrored those previously seen. For both accuracy, $F(1,39) = 244$, $MSE = 37.1$, $p < .001$, $\eta_p^2 = .86$, and RT, $F(1,39) = 130$, $MSE = 43041$, $p < .001$, $\eta_p^2 = .77$, a significant main effect of word type was shown, with greater accuracy ($EMM_{Noun} = 87.9$; $SE_{Noun} = 0.84$; $EMM_{Verb} = 66.3$; $SE_{Verb} = 1.47$), and faster speed of response ($EMM_{Noun} = 1096$ms; $SE_{Noun} = 29.1$ms; $EMM_{Verb} = 1632$ms; $SE_{Verb} = 54.7$ms), evident in the noun condition. For RT, where the data failed the necessary assumptions for parametric analysis, this was corroborated through non-parametric analysis ($p < .001$).

Summary of Results

Word class was shown to have a significant main effect on both the accuracy of single word production and RT. This effect was not influenced by group with, across the board, participants shown to make a greater number of errors in the verb condition, and name verb stimuli more slowly. This effect held when stimulus-led variability was controlled, suggesting no confounding effect of stimulus-led variability on the impact of word type on performance.

3.3.5 Individual Performance – Noun and Verb Naming

In addition to the group level analysis, individual performance in the verb and noun naming tasks was additionally examined. Scores 2 *SD*s removed from the mean of the control group were considered to be impaired. For an overview of findings, see Table 8.

Table 8.

Percentage of impairments as a function of word type and group

		PD	Control
		% Impairments	% Impairments
Accuracy (% correct)	Noun	25.0	4.00
	Noun – Adjusted Dataset	12.5	0.00
	Verb	18.8	4.00
	Verb – Adjusted Dataset	0.00	4.00
RT (ms)	Noun	18.8	8.00
	Noun – Adjusted Dataset	18.8	8.00
	Verb	25.0	4.00
	Verb – Adjusted Dataset	25.0	0.00

Across both tasks, taken at an individual level the percentage of individuals with PD who demonstrated word processing impairments (i.e., scores 2 *SD*s below the mean in the case of accuracy, or above the mean in the case of RT) was greater than that of controls. For accuracy, in both the PD and control group, a greater percentage of scores suggestive of impairment were seen in the noun condition. Neither pattern held in the control group however when stimulus-led variability was controlled for; under these conditions, only one control participant had a score 2 *SD*s away from the mean and this was in verb naming accuracy.

When considering RT, somewhat opposing patterns arose between individuals with PD and controls. In both the adjusted and non-adjusted dataset, the percentage of individuals with PD whose responses were 2 *SD*s away from the mean was greater in the verb condition. For controls the reverse pattern was evident (i.e., a greater percentage showed impaired performance in the noun condition). It should be stressed that this pattern was limited to a small number of participants and – as the lack of a significant interaction in the previous analysis indicated – did not present at a group level.

The profile of individuals who performed 2 *SD*s away from the mean (as just outlined) will be considered further in Section 3.3.6.6. At a group level, analysis concerned with verb and noun production accuracy was re-run without the control participant who indicated impaired verb accuracy performance. Please note that the adjusted dataset was used for this analysis. The results were largely analogous; a main effect of word type was again present ($p < .001$) but there was no significant interaction ($p > .10$). In this instance however a main effect of group – collapsed across word type – also presented, $F(1, 38) = 5.39$, $MSE = 63.0$, $p = .026$, $\eta_p^2 = .12$, with accuracy scores higher in the control group (PD: *EMM* = 75.3, *SE* = 1.40; Controls: *EMM* = 79.5, *SE* = 1.15). Whilst data for the ANOVA did not meet all necessary assumptions for parametric analysis, these assumptions were met for both of the main effects, thus meaning that no further analysis was required.

The same pattern was seen when considering the analysis concerned with noun and verb production RT. Mirroring findings shown when including the whole group of control participants, a main effect of word type was seen ($p > .001$) but no significant interaction ($p > .49$). A main effect of group also presented, $F(1, 37) = 5.95$, $MSE = 92831$, $p = .020$, $\eta_p^2 = .14$, with RT, collapsed across word type, faster in the control group (PD: *EMM* = 1614ms, *SE* = 54.6ms; Controls: *EMM* = 1078ms, *SE* = 25.9ms). Necessary non-parametric follow-up for the main within-group effect corroborated the main effect of word type (Sign test, $p > .001$).

Whilst these findings are interesting and provide useful further insight, it was not felt necessary or appropriate to remove the control participants who exhibited scores 2 *SD*s away from the mean from the study. There is no reason to suspect that this sample of individuals is unrepresentative of the wider sample from which they were drawn and, whilst the variability evident in the control group is an important point to consider, removing participants does not appear warranted.

3.3.6 Cognitive Processing

3.3.6.1 Set Shifting

To explore the effect of switch condition within each group, for both accuracy and RT a 2 (group) x 2 (condition) mixed factorial ANOVA was conducted. Accuracy was measured according to the number of errors made - i.e., the greater the score the greater the number of errors. Mean and median scores, according to group and condition, are provided in Table 9.

Table 9.

Mean (SD) and median (IQR) accuracy (as measured through the number of errors made) and RT (ms) scores in the set shifting task, as a function of group and switch condition

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Accuracy	Switch	0.81 (0.91)	0.64 (0.86)
		1.00 (1.00)	*0.00 (1.00)*
	No Switch	1.69 (2.24)	0.92 (1.08)
		1.00 (3.50)	*1.00 (1.50)*
RT (ms)	Switch	1398 (429)	1139 (340)
		1251 (460)	*1082 (394)*
	No Switch	1393 (478)	1093 (305)
		1206 (477)	*1059 (346)*

For accuracy, a main effect of condition was evident, $F(1,39) = 6.79$, $MSE = 0.96$, $p = .013$, $\eta_p^2 = .15$, with, collapsed across groups, more errors made in the no switch condition ($EMM_{Switch} = 0.73$, $SE_{Switch} = 0.14$; $EMM_{NoSwitch} = 1.30$, $SE_{NoSwitch} = 0.26$). No main effect of group existed, $F(1,39) = 1.75$, $MSE = 2.46$, $p = .194$, $\eta_p^2 = .043$, nor was there a significant interaction between variables, $F(1,39) = 1.80$, $MSE = 0.96$, $p = .187$, $\eta_p^2 = .044$.

Data for the ANOVA failed to meet the assumption of normality and homogeneity; the assumption of normality was similarly violated in the data for the within-subjects (switch condition) comparison, and a significant outlier additionally present. A Sign test which was run to corroborate findings did not support the presence of increased errors in the no-switch condition, $z = -1.02$, $p = .307$, $r = 0.16$.

For RT, a significant main effect of group was evident, $F(1,39) = 5.58$, MSE = 273336, $p = .023$, $\eta_p^2 = .13$, with, collapsed across conditions, stimuli responded to significantly more quickly in the control group (EMM_{PD} = 1396ms, SE_{PD} = 92.4; $EMM_{Control}$ = 1116ms, $SE_{Control}$ = 73.9). No main effect of switch condition, $F(1,39)$ = 0.90, MSE = 13652, $p = .349$, $\eta_p^2 = .023$ was evident, nor was there a significant interaction, $F(1,39) = 0.63$, MSE = 13652, $p = .432$, $\eta_p^2 = .016$.

Data for the ANOVA contained a significant outlier and failed the assumption of normality. Data for the between-subjects (group) comparison also failed the assumption of normality, and a non-parametric Mann-Whitney U test additionally run. This analysis reinforced previous findings showing stimuli, across the board, to be responded to significantly more slowly in the PD group (*Mean ranked score* = 26.3) as compared with the control group (*Mean ranked score* = 17.6) group, U = 116, $p = .024$, $r = 0.35$.

Summary of Results

No significant effect of group on performance accuracy was evident, nor was a significant interaction between group and condition (switch vs no switch) present. Whilst, collapsed across groups, findings from the ANOVA indicated condition to have a significant effect on accuracy, this finding was not corroborated by necessary non-parametric analysis.

There was no significant effect of attention shifting on the time taken to respond to stimuli, in either individuals with PD or controls. Collapsed across all conditions (i.e., regardless of attentional demands), responses were slower in the PD group.

3.3.6.2 Inhibition

Inhibition was considered along three sub-measures: inhibitory cost, distraction of control stimuli and the presence of semantic boost. For the first sub-measure, independent samples analysis was utilised to assess the influence of group on inhibitory cost. For the latter two sub-measures, mixed factorial ANOVAs were employed. To correct for multiple comparisons, Bonferroni adjustment was applied (adjusted $\alpha = .017$).

Inhibitory Cost

The data are presented in Table 10.

Table 10.

Mean (SD) and mean ranked inhibitory cost scores (ms), as a function of group

	PD	Control
	Mean (SD) *Mean ranked score*	Mean (SD) *Mean ranked score*
Inhibitory Cost (ms)	216 (115) *23.3*	171 (74.4) *19.5*

Because the data failed the assumption of normality (in the PD group), a non-parametric Mann-Whitney U test (adjusted $\alpha = .017$) was utilised to compare performance between groups. No significant effect of group was evident on inhibitory cost, $U = 163$, $p = .333$, $r = 0.15$.

Distraction of control stimuli (symbol vs word)

A 2 (group) x 2 (stimulus type) mixed factorial ANOVA (adjusted $\alpha = .017$) was conducted to assess the effect of the nature of a control stimulus on RT, in each group. The data are presented in Table 11.

Table 11.

Mean (SD) and median (IQR) RT (ms) scores in the Stroop task, according to group and stimulus type (words and symbol)

	PD	Control
	Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Word (ms)	864 (141) *836 (183)*	843 (154) *836 (217)*
Symbol (ms)	852 (148) *834 (157)*	784 (150) *746 (192)*

Analysis revealed a significant main effect of stimulus type, $F(1,39) = 8.26$, $MSE = 2966$, $p = .007$, $\eta_p^2 = .18$, with, collapsed across group, symbols (EMM = 814ms, SE = 28.9) responded to significantly faster than control words (EMM = 858ms, SE = 36.1). There was no main effect of group, $F(1,39) = 0.92$, $MSE = 41677$, $p = .342$, $\eta_p^2 = .023$ or interaction between variables, $F(1,39) = 3.52$, $MSE = 2966$, $p = .068$, $\eta_p^2 = .083$.

Data for the ANOVA failed the assumption of normality and contained a significant outlier. Data for the within group (stimulus type) comparison violated the same assumptions, and a non-parametric Sign test consequently utilised to confirm accuracy of the indicated main effect. Symbols were again indicated to exert a facilitatory effect on RT, however in the non-parametric analysis this did not meet significance, z = -1.87, p = .061, r = 0.29.

Semantic Boost

A further 2 (group) x 2 (stimulus type) ANOVA (adjusted α = .017) was conducted to assess whether congruent stimuli offered any ‘semantic’ boost, and whether the influence of any such effect varied according to group. To assess this, performance in the congruent and control word conditions was compared. The data are provided in Table 12.

Table 12.

Mean (SD) and median (SD) RT (ms) scores in the Stroop task, as a function of group and stimulus type (congruent and control)

	PD	Control
	Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Congruent (ms)	920 (154) *928 (280)*	899 (219) *874 (322)*
Control (Word; ms)	864 (141) *836 (183)*	843 (155) *836 (217)*

Stimulus type was shown to have a significant main effect on RT, F(1,39) = 9.95, MSE = 6147, p =.003, η_p^2 = .20, with responses faster in the control condition, collapsed across groups ($EMM_{Congruent}$ = 910ms; $SE_{Congruent}$ = 31.5; $EMM_{ControlWord}$ = 854ms, $SE_{ControlWord}$ = 23.9). No main effect of group, F(1,39) = 0.16, MSE = 54854, *p* =.693, η_p^2 = .004 or significant interaction, *F*(1,39) = 0.00, *MSE* = 6147, *p* =.991, η_p^2 = .000, was found.

Data for the ANOVA contained significant outliers and failed the assumption of normality. The same assumptions were violated in the data for the within-subjects (stimulus type) comparison and a non-parametric equivalent (Sign test) additionally conducted. This analysis upheld the indicated main effect of stimulus type, $z = -3.75$, $p < .001$, $r = 0.59$.

Summary of Results

Results indicated no difference in inhibitory control (as measured through the inhibitory cost score) between groups. Whilst it was indicated that, in the control condition, symbols were responded to significantly faster than words across all participants, this was not supported by the non-parametric analysis. The expected 'semantic' boost effect was not evident in either group with, collapsed across participants, control words responded to significantly more quickly than congruent words.

3.3.6.3 Working Memory Updating

For both accuracy and RT, a 2 x 2 mixed factorial ANOVA was conducted to assess the influence of group and task speed on updating ability. The data are presented in Table 13. Accuracy scores were out of 12, per condition.

Table 13.

Mean (SD) and median (IQR) accuracy and RT (ms) scores in the 2-back task, as a function of group and task speed

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Accuracy	Slow	10.4 (1.89)	10.7 (1.77)
		11.0 (3.00)	*11.0 (2.00)*
	Fast	10.6 (1.26)	10.8 (1.80)
		11.0 (2.00)	*12.0 (2.00)*
RT (ms)	Slow	1286 (509)	1110 (414)
		1318 (757)	*1040 (561)*
	Fast	1286 (587)	1114 (454)
		1013 (998)	*977 (468)*

For accuracy, no significant main effects of either speed, $F(1,39) = 0.42$, $MSE = 1.09$, $p = .519$, $\eta_p^2 = .011$, or group, $F(1,39) = 0.30$, $MSE = 4.84$, $p = .589$, $\eta_p^2 = .008$ were revealed, nor was there any interaction between variables, $F(1,39) = 0.020$, $MSE = 1.09$, $p = .887$, $\eta_p^2 = .001$.

Similarly, analysis revealed there to be no main effect of speed, $F(1,39) = 0.002$, $MSE = 27290$, $p = .964$, $\eta_p^2 = .000$ or group, $F(1,39) = 1.35$, $MSE = 437338$, $p = .252$, $\eta_p^2 = .033$, on RT, and no significant interaction between variables, $F(1,39) = 0.003$, $MSE = 27290$, $p = .955$, $\eta_p^2 = .000$. Note, data for both ANOVAs failed the assumption of normality and contained significant outliers.

In summary, neither task speed nor group was found to have a significant effect on working memory updating, nor did a significant interaction exist between variables. In other words, the performance of individuals with PD was comparable to that of controls, and in neither group was performance influenced by task speed.

3.3.6.4 Short Term and Working Memory

The influence of group on forwards and backwards digit span – assessing storage capacity as well as both storage and manipulation of information in working memory, respectively – were conducted using independent samples analyses. The data are presented in Table 14. The maximum possible span score was 9.

Table 14.

Mean (SD) and mean ranked scores in the digit span tasks, as a function of group

	PD	Control
	Mean (SD) *Mean ranked score*	Mean (SD) *Mean ranked score*
Forwards	6.92 (1.20) *20.7*	7.03 (1.24) *21.2*
Backwards	5.33 (1.53) *19.7*	5.57 (1.52) *21.9*
Difference	1.58 (1.09) *21.6*	1.45 (1.06) *20.6*

There was no difference in forwards, $t(39) = -0.28$, $p = .781$, $d = -0.090$, or backwards, digit span, $U = 222$, $p = .565$, $r = 0.090$, between groups. There was, additionally, no significant effect of group on the difference in scores between tasks (i.e., processing cost), $t(39) = 0.38$, $p = .706$, $d = 0.12$.

Results therefore indicated no group difference in short term memory capacity, or the ability to store as well as manipulate information in working memory. Furthermore, the processing cost (i.e., difference score) was comparable between groups.

3.3.6.5 Processing Speed

Independent samples analysis was run to explore the effect of group on processing speed. One control participant was excluded from analysis due to technical issues during the task: thus *n* = 40. The data is provided in Table 15.

Table 15.

Median (IQR) and mean ranked processing speed scores, as a function of group

	PD	Control
	Median (IQR) *Mean ranked score*	Median (IQR) *Mean ranked score*
Processing Speed	68.0 (17.0) *18.3*	68.0 (23.2) *22.0*

No significant difference in processing speed score between groups was indicated, *U* = 228, *p* = .292, *r* = 0.16, demonstrating group to have no significant influence on processing speed.

3.3.6.6 Individual Performance – Cognitive Processing

In addition to the group level analysis, individual performance in each of the cognitive tasks was additionally examined. Scores 2 *SD*s removed from the mean of the control group were considered to be impaired. For an overview of findings, see Table 16.

Table 16.

Percentage of participants with cognitive impairments as a function of task type and group

	PD	Control
	% Impairments	% Impairments
Set Shifting – Switch Errors	6.25	4.00
Set Shifting – Total Errors	25.0	8.00
Inhibition (Inhibitory Cost Score)	18.8	0.00
Updating	0.00	8.00
Short Term Memory (Forwards Span)	0.00	0.00
Working Memory (Backwards Span)	0.00	0.00
Processing Speed	0.00	4.17

No individuals received a score 2 *SD*s below the mean in either of the span tasks. When considering processing speed, the vast majority of participants received a score within 2 *SD*s of the mean, with the exception of one control participant. There was no indication of any impairment of working memory updating in the PD group however, in the control group, 8.00% of control participants showed an impairment. Of the remaining executive functioning tasks, no control participants demonstrated an impairment of inhibitory control, whilst three participants in the PD group did so. Finally, one individual with PD and one control participant demonstrated an impairment in set shifting, as measured through the number of errors made in the switch condition. Observation would suggest that, in the case of the control participant, the increased error rate was accompanied by noticeably shorter RT, suggesting that increased RT may have come at the cost of decreased accuracy. No such pattern was evident in the PD group. When the total number of errors in the set shifting task was measured, the number of individuals who presented with impaired scores noticeably increased; in line with the suggestion from the group level analysis that in general, where errors were made they were more likely to be made in the non-switch condition. From the overall patterns observed here it can be concluded that, as well as showing comparative performance within the M-ACE, no individual within the PD group met the Level 1 Diagnostic Criteria for PD-MCI (Litvan et al., 2011)[12].

Of the nine individuals who received scores 2 *SD*s away from the mean in the language tasks (utilising the adjusted dataset), four– all in the PD group – also showed impaired performance in a cognitive task. In one instance this related to shift cost score in the set-shifting task, in a further two instances this related to the overall number of errors in the set shifting task and in the fourth instance to the inhibitory cost score. In two of these four cases, participants showed impairment in both the noun and verb task, as well as one cognitive task. All remaining participants who received a score 2 *SD*s away from the mean in the language tasks did so in a single domain - i.e., either in the verb or the noun naming condition.

At a group level, analyses concerned with set-shifting, working memory and processing speed were re-run excluding any control participants whose scores were 2 *SD*s from the mean. In the case of set-shifting, impairment was judged only in

[12] Litvan et al. (2011) outline two separate criteria for the diagnosis of PD-MCI, which vary in their assessment methods. Level I – also termed 'abbreviated assessment' – consists of impairment indicated through an appropriately validated global cognitive ability instrument or through impairment evidenced in at least two tests from a neuropsychological battery which is limited either through not encompassing all five cognitive domains (i.e., attention and working memory, executive functioning, language, memory and visuospatial) or through including all five cognitive domains but including less than two tests in some of these domains. Level II assessment requires at least two tests to be performed in each cognitive domain, and impairment to be indicated in at least two of these (either from the same or different domains).

relation to switch cost, not overall errors. Findings from the set shifting task exactly mirrored those seen when all control participants were included. Namely, a significant main effect of switch condition was seen (p = .010) which was not corroborated by necessary non-parametric follow up testing (Sign test; p = .210). No other effects were significant (all p > .23). The same was true in the working memory updating (all p > .087) and processing speed (p = .395) tasks.

Additionally, analyses concerned with noun and verb accuracy and RT were also re-run with data from the same control participants just outlined removed. With regards to accuracy, results diverged only slightly from those previously seen. Again, a significant main effect of word type was evidenced (p < .001) but no significant interaction with group seen (p = .121). In contrast with the previous whole group analysis, a significant main effect of group was indicated, $F(1,36) = 4.38$, MSE = 75.6, p =.044, η_p^2 = .108, with scores, collapsed across word type, lower in the PD group. Data for both the ANOVA and indicated main effect of group did not meet all necessary assumptions, and a Mann-Whitney U test consequently run. This did not corroborate a main effect of group, U = 242, p = .051, d = 0.69. With regards to verb and noun RT, findings were exactly as seen in the whole group analysis, with a significant main effect of word type evidenced (p > .001). No other main effects, or the interaction, were significant (all p > .14).

Collectively, these findings would indicate that variability, in terms of cognitive performance, in the control group did not account for the lack of any significant difference between groups, either in the cognitive tasks themselves or when considering noun and verb production. As previously mentioned in Section 3.3.5 in relation to individual performance in the language tasks, there was nothing to indicate that the profile of the control group within this study was not representative of the wider population from which it was drawn. Thus, no reason to exclude these participants from further analysis conducted to address the experimental research questions presented.

3.4 Discussion

3.4.1 Language Processing

Sentence Comprehension

Findings from the sentence comprehension task pointed towards a specific deficit in the PD group, confined to the processing of complex constructions containing an embedded clause. When findings were examined at an individual level, this alteration was traced to four participants; indicating that, overall, a greater percentage of individuals with PD showed no syntactic processing impairment. The finding that only a subset of individuals with PD showed an impairment of comprehension is in line with findings from the current literature (e.g., Angwin et al., 2005; Grossman et al., 2002). Again in line with previous findings (Angwin et al., 2005), observation of the data did not point towards any obvious classifying demographic or clinical features of the impaired comprehension subgroup. Years of education and gender were mixed, and the time (in years) since diagnosis varied.

Some interesting patterns did however emerge when individual performance in the cognitive tasks was considered. Specifically, it was observed that the two individuals – one individual with PD, and one control – whose score was 2 *SD*s away from the mean in the set shifting task (counting just switch errors) both made errors in the embedded sentences task. Of the remaining three PD participants in the altered comprehension sub-group, one had an inhibitory cost score more than 2 *SD*s away from the mean, and one had a score more than 2 *SD*s away from the mean when considering overall number of errors in the set shifting task. The final participant showed no alteration in any cognitive ability. Whilst the conclusions that can be drawn from the current data are limited, the observed pattern again appears to be broadly in line with that of previous studies (Grossman, Lee, et al., 2002; Hochstadt, 2009) which have related the altered comprehension seen in PD to the ability to inhibit and move away from prepotent, expectation based thematic role assignment and enable correct interpretation. That being said, one individual within the altered comprehension PD sub-group did not show impaired performance in any cognitive measure whilst, conversely, two individuals with PD who did show impaired performance within the Stroop task were not in the altered comprehension sub-group. This pattern could suggest that the mechanisms underpinning altered embedded clause processing in PD varies between individuals, and/or that the relationship between certain executive processes – i.e., inhibition – and syntactic processing is not a direct one but mediated by other factors.

The finding that only performance within the ‘Embedded Sentences’ subtest was altered in PD is in contrast to findings reported by Bocanegra et al. (2015), who utilised the same comprehension task. Within that study, PD participants both with and without MCI were shown to perform more poorly, as compared with controls, on both the ‘Touching A with B’ and ‘Embedded Clauses’ subtest. When executive functioning ability was adjusted for, the authors found that the difference seen in the ‘Embedded Clauses’ subtest did not hold, whereas that seen in the ‘Touching A with B’ subtest remained, leading to what the authors discussed as “…two patterns of syntactic impairment…” (Bocanegra et al., 2015, p. 242). The link between executive functioning and performance within the ‘Embedded Sentences’ subtest appears to be largely in accord with the findings from this study. The question as to why the group of individuals with PD in Bocanegra et al.’s (2015) study showed altered performance in the ‘Touching A with B’ subtest whilst the group of individuals with PD in this study did not, however, remains.

The group of non-MCI PD participants in Bocanegra et al.’s (2015) study were younger on average than those involved within this study, but as a group had a similar mean disease duration. Information regarding individuals’ general cognitive ability was not provided in Bocanegra et al.’s (2015) study, making it impossible to rule out the possibility that a difference in general, global cognitive functioning is underpinning the difference seen. In light of the fact that disease duration was similar between the groups in this and Bocanegra et al.’s (2015) study but average age was different, an alternative hypothesis which could tentatively put forward is that the difference in performance in the ‘Touching A with B’ subtest reflects differences in disease trajectories between the groups, according to the age of diagnosis. From the information available, it was calculated that individuals within Bocanegra et al.’s (2015) study must, on average, have been younger at the age of diagnosis than the group within this study. Thus, it may the case that the comprehension of syntactic structures of the type tested within the ‘Touching A with B’ subtest are differentially impaired in PD according to factors relating to disease progression. Research would indicate that the rate of cognitive decline in the earlier phases of PD may vary according to the age of onset (Kempster et al., 2010) and it seems plausible therefore to consider that the rate of language function decline may vary similarly. Understanding what might be underpinning the altered comprehension of these specific syntactic structures – i.e., whether it is linguistic in nature, or perhaps is a reflection of general cognitive processing, as opposed to specific executive abilities – could provide useful information not only regarding language processing in PD, but potentially contribute to the body of work concerned with identifying indicators which may predict different trajectories of cognitive decline in PD (e.g., Kehagia et al., 2013).

In turn, it would be useful to try and further unpick the degree to which any impairment lies within processes core to sentence comprehension itself and to what degree any impairment arises from the nature of the task. It is interesting, for example, that within Walsh, Smith, and Lafayette's (2011) study, individuals with PD again showed an impairment in the comprehension of embedded clauses, in this instance however in an on-line task within which working memory demands had, through the design of the task, effectively been reduced. The fact that an alteration in the comprehension of embedded clauses has been seen both in a condition within which the working memory demands of the task have been purposefully reduced (i.e., within Walsh et al.'s, 2011 study) and in a condition within which they have not (i.e., within this study) would suggest that something other than working memory demands are underpinning the pattern of altered comprehension seen across both studies.

Whilst a number of previous studies have employed the comprehension tasks utilised within this study and have indicated them to be sensitive to PD, as previously considered in Section 3.2.2 questions have been raised about the suitability of aphasia batteries in the assessment of the language processing in PD, with it being intimated in particular that on-line tasks may be more suited to the task (see Miller, 2017 for discussion regarding PD specifically, and Shapiro, Swinney, & Borsky, 1998 for discussion regarding the advantages of on-line tasks more broadly). The investigation and comparison of performance within both on- and off-line tasks in future studies appears likely to be fruitful (Shapiro et al., 1998), particularly when combined with dual-task paradigms allowing for specific processing demands (for example, attentional demands) to be manipulated.

Given that dual-tasking has been shown to be vulnerable in PD (Dirnberger & Jahanshahi, 2013) it is reasonable to hypothesise that, even in this group of individuals with PD who compared comparably with controls in all cognitive measures, a greater difference in sentence processing may have appeared had greater cognitive processing demands been placed (in the form of a dual-task paradigm). Manipulating these demands (e.g., increasing specific executive demands) within future studies and investigating under exactly which demands altered language performance in PD is induced could be elucidating - both in relation to PD, and our understanding of the role executive control and basal ganglia circuitry in language processing more broadly. Additionally, including a combination of both on- and off-line tasks would enable constituent sub-processes to be examined in detail, to a degree which is not possible with offline tasks alone (Shapiro et al., 1998).

Noun and Verb Processing

One reason for including a noun production task within this study was to allow for noun and verb production to be compared. A second reason was to explore the effect that the degree of motion associated with a noun's meaning had on production in individuals with PD, as compared with controls. Findings relating to this second aim will be discussed first.

Noun Naming – the effect of associated motion

Collapsed across all participants, the motion associated with a noun's meaning was found to have a facilitatory effect on noun naming accuracy. Specifically, nouns with a high degree of motion associated with their meaning (animate nouns) were found to be named more accurately than those with no associated motion. No difference in performance between the PD and control group was evidenced. The finding that the level of motion associated with the noun's meaning did not differentially affect the accuracy of noun naming in the PD group is akin to that reported by Bocanegra et al. (2017), who found no difference in the accuracy of noun naming in individuals with PD without MCI, regardless of the degree of manipulability associated with those nouns. It is nonetheless interesting to consider what these findings might indicate about noun processing in PD, and why, across all participants, action appeared to have a facilitatory effect.

The nouns included within the 'some motion' condition within the task employed were a combination of objects which are either physically manipulated by people (e.g., 'axe') and those which, as a natural part of their being, have some level of motion associated with them (e.g., 'eye'), but are not physically manipulated in quite the same sense. Across both, in the prepared stimuli, the focus was on the object and, whilst it did appear in context, the backdrop provided was neutral, with no action actively depicted. Thus, the motion associated with the noun was covertly expressed, with the level of motion evident in the picture not varying significantly between conditions. The fact therefore that the PD group did not show any impairment, or difference in their pattern of performance in this task, could indicate that, when the situation within which an object is observed is neutral, the degree of motion associated with said object does not have any discernible effect (separate to that which may exist in general) on the ability of individuals with PD to name it.

This supposition is supported both by the previously reported findings from Bocanegra et al. (2017) – who, from the information available, appeared to present objects in a way analogous to this study – and to, a degree, those reported by Humphries et al. (2019), in their study looking at the processing of action metaphors in PD. In this latter study, the authors found that action only had an effect on response latency in the PD group in the case of predicate, but not nominal, metaphors. Whilst within the predicate metaphors, the ‘action’ was occupying the grammatical position of verb within the sentence, within the nominal metaphors it was acting as noun, occupying the grammatical position of complement – e.g., ‘the puzzle was a *logic cartwheel’*. Thus, again appearing to suggest that whilst action does have an influence on processing in PD when it is depicting movement, when it is depicted as a static object, the ‘covert’ action associated with it does not have an effect.

The discussion presented here does not preclude the possibility that such an affect may exist when the object is presented in a context within which it is being used within its intended action. Indeed, it would be interesting, in future studies, to compare this with performance within a paradigm within which the manipulable objects are couched within scenes depicting both high and low action situations and assess whether the context within which the object is placed – and therefore the degree of action suggested to be associated with the object through the scene in which it is appearing – influences production accuracy.

There is limited context within which to consider the overall pattern of performance – i.e., the indication that nouns with a higher degree of motion associated with them were named more accurately – collapsed across participants, as previous studies concerned with the motion associated with nouns have focussed solely on manipulable vs non-manipulable objects (Bocanegra et al., 2017; Cotelli et al., 2007). Nonetheless, it is interesting to consider this finding in relation to the work of Breedin et al. (1998), who discussed the role of contextual constraint on verb retrieval. The high motion nouns utilised within this study were all animate objects, the vast majority of which were animals. Whilst there is of course some variability, in general, the context associated with various animals is limited, and specific. In contrast, the contexts within which the objects utilised within the no motion group could occur were vast, and variable in nature. Thus, whilst the animate nouns might activate one meaning and associated context, the no-motion nouns might activate multiple – placing greater demands on control and selection processes. Thus, as per the theory put forward that the verb processing deficit in PD represents an impairment of executive control and the ability to inhibit prepotent responses, it could be supposed that the difference in noun naming exhibited here may reflect different executive control demands.

This, in turn, presents the question as to why this effect did not separate the performance of individuals with PD from controls, as might have been expected given findings from previous studies within which the number of conceptual or lexical options available have been investigated (e.g., Crescentini et al., 2008; Silveri et al., 2018). This could simply be a reflection of the language and executive control ability of this group of individuals with PD or be a reflection of individual variability. There is however the possibility, too, that any impact of increased selection demands on language processing in PD only appears under certain constraints, or when a particular threshold has been reached. Such that, whilst an effect is not seen in situations involving the naming of objects, it does appear in instances within which nouns are derived from other word classes (Silveri et al., 2018) or in tasks which require the production of a verb from a given noun (Crescentini et al., 2008).

Noun vs Verb Production

Comparison of performance in the verb and noun naming task indicated no significant difference in the pattern of performance between the PD and control group. That is, whilst a significant effect of word type was seen, with answers in the noun naming task provided more quickly and with a greater degree of accuracy, this effect was seen in both individuals with PD and control participants. Although this is not the only study to observe no significant difference in overall verb naming ability between individuals with PD and controls (see Signorini & Volpato, 2006), generally the weight of evidence within the current literature is tipped towards the presence of a selective verb deficit in PD, leading to a number of questions regarding why the findings seen here appear to differ from the majority of those previously reported (see Cotelli et al., 2007; Rodríguez-Ferreiro et al., 2009, for example).

One potential for the differential finding is the impact the conditions placed on the verb list. Whilst we collapsed all conditions here, because the same verb list was also utilised within the analysis exploring the effect of action and grammatical complexity on verb naming, the criteria for the target verbs included were narrower than those in previous studies. This, in turn, presents the possibility that the verb production task may have been more difficult than that utilised within previous studies, both for individuals with PD and control participants. Indeed, inspection of the data indicated that, even when stimulus-led variability was controlled for, noticeable variability existed in the verb condition in the control group, with accuracy scores ranging from 46-85% and average RT from 941-2154ms. There is the possibility, therefore, that the lack of any significant difference in the pattern of performance between individuals with PD and controls may be less reflective of a lack of altered processing in the PD group, and more a reflection of the degree of variation evident within the control group.

That being said, removing the data of the control participant who received a score more than 2 *SD*s below the mean in verb production accuracy and re-running the analysis returned the same non-significant interaction. And, from the results presented in Section 3.3.6.6, it does not appear that any differences in patterns of linguistic performance between the groups are being masked by cognitive variability within the control group, either. Where variability in language performance in the control group does seem to be having an influence on findings however is when considering overall (i.e., verb and noun combined) word naming performance. Specifically, removing the participant whose score was more than 2 *SDs* away from the mean in the verb naming task revealed a significant main effect of group – in both instances with sizable effect sizes – with accuracy scores higher and RT faster in the control group. As previously outlined, it does not feel appropriate to remove this participant from any further analysis conducted as part of the study and, more generally, there is nothing to suggest that the variability seen in the control group is not representative of the wider population from which the group was drawn. Nonetheless, the effect observed is important to bear in mind particularly in the context of future research.

The conclusions that can be drawn regarding the performance of the control group within this study are limited. The findings here would suggest that including an additional control group of younger adults in future studies may be beneficial and would allow for patterns of performance in neurotypical adults of different ages to be considered and compared. Such inclusion could further provide useful information regarding the pattern of cognitive alteration in PD as compared with typically ageing controls; indeed, conducting such a study using a longitudinal design could be particularly elucidating. Whilst cognitive variability in the control group does not appear to have influenced findings in the language tasks in this study, subtyping and matching participants according to performance within particular cognitive domains (in the absence of MCI and general cognitive alteration) could also be beneficial within future studies.

It is additionally worth considering here the potential variability in the make-up of conceptual representations which may present between individuals. Each individuals' experience is different, and it seems plausible therefore to assume that the information from which individual's conceptual representations are built will be commensurately different (see Meteyard & Vigliocco, 2018, for further discussion). This effect is likely to be greatest for action verbs according to whether the individual has routinely carried out the action concerned themselves and thus has stored motor patterns for that action, or whether knowledge is more reliant on visual information. That being said, research indicating a role of affective information in the representation of abstract words (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011) could equally lead to variation in the representation of abstract representations. Nonetheless, if one is working under the hypothesis that the degradation of motor programmes may be underpinning altered verb naming ability in PD, one could expect that the functional impact of this will vary according to the degree to which the individuals' motor experience forms the conceptual representation. This could therefore add an additional source of potential variation, alongside any variability relating to individual pathology in PD group. Again, due to the constraints placed on the target verbs, there is the potential that this effect may have been amplified within this study.

Also worthy of consideration is any potential impact that the way in which nouns and verbs were considered and categorised may have had on the results seen. Again, whilst not considered within this analysis, target words within both the noun and the verb condition were divided according to the action or degree or motion associated with their meaning. Thus – whilst divided according to the grammatical position they occupy (i.e., according to word class), there is the potential that some of the low action verbs chosen may, theoretically, have had a lower degree of action associated with their meaning than some of the animate nouns. And, to refer back to the point made in the previous section, there is equally the potential that the number of competing semantic alternatives associated with some of the nouns may have been higher than that of the verbs. So, in a sense, two potential confounds exist, both of which may have masked any differences between the word classes which may have been seen in other studies because, in those studies, nouns were consistently lower action and/or had fewer competing alternatives.

A final aspect to consider is the general cognitive ability and disease duration of the PD groups within this and previously reported studies. Whilst information regarding disease duration is not available within Cotelli et al.'s (2007) work, such information could be retrieved from the study conducted by Rodríguez-Ferreiro et al. (2009). In both this and Rodríguez-Ferreiro et al.'s (2009) study, the word lists in each condition were matched according to frequency and age of acquisition and there was no significant difference in the general cognitive ability of the PD and control groups. Where the PD groups diverged, however, was in average disease duration, with disease duration noticeable higher in Rodríguez-Ferreiro et al.'s (2009) study (10.2 years, as compared with 6.98 years in this study). This – potentially combined with the nature of the verbs employed, given the findings reported by Kemmerer et al. (2013) to indicate that the specific deficit in 'cutting' verbs observed increased in line with disease duration – could go some way to explaining the differences seen.

In some contradiction, however, the time since diagnosis of the non-MCI group in Bocanegra et al.'s (2017) study was actually lower (5.18 years) than that in this study. Whilst it was specified in Bocanegra et al.'s (2017) study however that all individuals with PD received a score above that suggestive of MCI on the cognitive screen utilised, scores for the measure were not provided, and it is therefore not clear if, whilst not meeting the criteria for MCI, there was a significant difference between the PD and control group in general cognitive ability scores. Thus, the difference in finding between this study and Bocanegra et al.'s (2017) could reflect cognitive differences between the groups. Including a condition of increased cognitive demand within future experimental studies – for example, a dual task paradigm – under which an impairment of language processing might be able to be induced would provide useful information regarding under what processing conditions language difficulties may present in PD, even when no overt cognitive alterations present (see also Auclair-Ouellet, Lieberman, & Monchi, 2017 for related discussion).

Finally, but potentially importantly, the analysis conducted by Bocanegra et al. (2017) differed from that conducted here: specifically, two between-subjects comparisons were conducted, one concerned with performance in the noun naming task and one with production in the verb naming task. Thus, whilst it was shown that a significant difference in performance existed between groups in the action (located specifically to high action verbs) but not the object condition, it was not established whether there was any difference in the noun-verb differential between the groups.

3.4.2 Cognitive Processing

Within this study, five cognitive abilities were examined: attentional set shifting, inhibition, updating, short term and working memory (storage capacity plus storage and manipulation) and processing speed. Findings from each of these are discussed in turn.

Set Shifting

In line with the findings from the study employing the paradigm upon which the task utilised here was modelled (Cools et al., 2001b), no alteration in set shifting ability – as measured through the number of errors observed, per switch condition – was evident in the PD group. Tasks assessing set-shifting through the application of 'broader' tasks (such as the Trail Making Test, for example) indicate mixed results, with some reporting altered performance in individuals with PD without dementia (e.g., Colman et al., 2009) but others not (Roberts & Post, 2018). It is noted that whilst, collapsed across all participants, a presence of a greater number of errors being made in the no-switch condition was indicated, this was not corroborated through non-parametric analysis.

Again, in line findings from the study upon which this task was modelled, a significant main effect of group on RT was seen, with individuals in the PD group responding significantly more slowly – regardless of condition – than controls. Such a finding could point towards overarching bradyphrenia in the PD group, in the absence of any decline in set shifting ability. That being said, a general reduction in RT in the PD group was not evidenced in other tasks (such as the updating task, for example), pointing away from general cognitive slowing being the sole cause of the alteration seen here (a finding in line with previous research; Spicer, Brown, & Gorell, 1994). One could tentatively hypothesise that the generally slowed response seen in the PD group was a strategy employed to maximise accuracy. And, in turn, the fact that this was not seen in the other cognitive tasks employed could suggest either that individuals had more difficulties with this set shifting task, and/or were more cognisant of the difficulties, and spent more time on the task accordingly. It would be interesting in future studies therefore, to investigate whether increasing the demands of the task through including a time constraint would alter the outcome seen.

Where findings diverged from those reported by Cools et al. (2001b) was in the interacting effect of condition. In contrast to Cools et al's. (2001b) findings, there was no significant difference in RT according to condition. The finding does not appear to be attributable to any difference in the general cognitive ability of the PD groups in each study. Whilst direct comparison cannot be made as Cools et al. (2001b) utilised a different measure of general cognitive functioning (the Mini Mental State Examination; Folstein et al., 1975), in both studies the groups (i.e., individuals with PD and controls) were matched on the score of general cognitive ability and in both these scores were similarly high. What is interesting to bear in mind, however, is the difference which exists between the task of Cools et al. (2001b), and the task conduced here. Within their task, Cools et al. (2001b) included a third condition: ‘cross-talk’ vs ‘non cross-talk’. Within the current study, only the cross talk condition was adopted such that, in all instances, the target symbol (whether that be the letter, or the number) was accompanied by a non-neutral character (i.e., whichever symbol was opposite to that of the target). Whilst, in Cools et al.’s (2001b) study, increased switch costs – as measured through increased RT – were only evident in the cross-talk condition, the fact that the same pattern did not present here could be a result of the lack of that third condition. In other words, it presents the possibility that the increased switch cost in the cross-talk condition occurred in part because of the presence of the non-cross talk condition, and the additional complexity that introduced.

Inhibition

Analysis indicated no reduction in inhibitory control (as measured through the inhibitory cost score) in the PD group, as compared with controls. This is in contrast to findings reported by Obeso et al. (2011) who observed an increased ‘Stroop effect’ in the PD group which held when scores on a measure of general cognitive performance was controlled for. Again, this could simply reflect the preservation of inhibitory control in this group of individuals with PD. It is however worth considering whether any differences in the way the Stroop task was conducted within this study, as compared with Obeso et al. (2011) contributed to this finding. Most notably, the Stroop task conducted here employed a mixed trial-block procedure, whilst that conducted by Obeso et al (2011) employed a block procedure within which the series of control stimuli were first shown, followed by the series of incongruent stimuli. Further, more conditions were included within the task employed within this study which, when presented in the mixed trial block design, meant that ‘curveballs’ were continually being thrown up, reducing individuals’ ability to predict the nature of the stimulus appearing next and likely leading to increased RTs, as compared with Obeso et al.’s (2011) design.

That in itself would not necessarily explain the difference in findings however, as one might expect a commensurate increase in average RT in both conditions. What might have made an additional difference too, however, is the nature of the control stimuli. The control condition within this study was divided into two types: neutral words, and symbols. Collapsed across both groups, a trend towards a significant main effect of condition type was indicated, with symbols responded to faster than neutral words. There is the possibility, therefore, that the control condition in Obeso et al.’s (2011) study, which also required participants to name the colour of a symbol (in that instance a shape) could have resulted in faster completion times in the control condition leading, in turn, to a greater differential between completion time in the control and experimental condition.

The final effect explored within this task was that of ‘semantic boost’: in other words, whether situations within which the word written matched the colour ink the word was written in would create a processing advantage. Interestingly, again collapsed across both groups, responses were actually found to be significantly slower in response to congruent stimuli, suggesting that the appearance of congruent words actually tripped participants up. In a way, this finding makes perfect sense. To ‘succeed’ at the task, participants were required to be able to override the prepotent response of reading the word aloud and name the colour of the ink. Realisation, in the congruent condition, that the word was the same as the colour of the ink may have caused people to stumble because their controlled response (the colour) was also the prepotent response (the word), which may have caused them to pause and assess whether they had made a mistake (i.e., mistakenly read the word, rather than name the colour of the ink). It may be the case too that, as Kane and Engle (2003) discuss, the inclusion of congruent stimuli also increased the working memory demands of the task, as response to those stimuli goes against the overall rules adopted within the task to ignore the written word. Whilst the congruent condition was not included in the analysis concerned with inhibitory control, going on this theory, it seems perfectly plausible to propose that the appearance of congruent condition could have slowed responses to the stimuli immediately following, until participants (re)gained confidence in the strategy of applying the controlled response. Collectively, these differences in task may have led to the difference in the results seen in this study, as compared with those reported previously – and the impact of these differences might be worthy of consideration within future studies.

Updating

No alteration in the ability to update information in working memory was evident in the PD group, as measured through accuracy of responses. This is in line with the behavioural findings from some studies (Marklund et al., 2009) but not others (Miller, Price, Okun, Montijo, & Bowers, 2009). Importantly though, whilst the design adopted in the former was similar to that employed here, in the latter the task was significantly longer, employing 25 trials per block in contrast to the eight employed here. Further, in Miller et al.'s (2009) study the blocks became significantly more difficult, with the first employing a 0-back design, and the final a 3-back design. Additionally, the time individuals were given between blocks was short (5-20s), whereas no restriction was placed on the length of time participants were allowed to rest before moving on to the next task in this current study. It may be, therefore that any alteration in updating only presents in PD when required over a relatively lengthy period and, potentially, when the demands placed across this period increase with time. The difference in findings between the studies does not appear to reflect any difference in general cognitive ability between PD participants with, from the information available, performance appearing to be similar across studies.

As with the measure of accuracy, no significant difference in RT was found between individuals with PD and controls; in line with previous studies (Marklund et al., 2009; Miller et al., 2009).

Short Term and Working Memory

No difference in short term memory capacity – as measured through forwards digit span was observed, in line with previous findings (Brønnick et al., 2011; Gilbert, Belleville, Bherer, & Chouinard, 2005; Lewis, Slabosz, Robbins, Barker, & Owen, 2005). No difference was seen either in backwards digit span, which required additional stimulus processing as well as storage. This finding is more surprising, as an alteration in the ability to manipulate information in working memory in a PD cohort similar to that involved within this study has been previously reported, albeit using slightly different tasks (Lewis et al., 2005).

Some questions have been raised however, regarding exactly what backward digit span is measuring, and the degree to which executive resources are being employed within this process. Whilst conducted on neurotypical, young adults, findings from St Clair-Thompson and Allen (2013) would suggest that the backwards digit span task may in fact make minimal demands on executive control resources, but greater demands on visuospatial resources, through the application of visual strategies. Thus, comparable performance between individuals with PD and controls within the backward digit span task could, very cautiously, be hypothesised to represent preserved visuospatial-processing skill, to the degree required for successful completion of this task (and, indeed, performance within the visuospatial subsection of the M-ACE was found to be comparable between the groups: $U = 224$, $p = .448$).

In future studies therefore, it may be appropriate to consider the application of an alternative task to assess working memory manipulation in PD and thus allow for reliable comparisons between this and updating ability to be conducted.

Processing Speed

Processing speed was assessed using a visual inspection time task, chosen due its non-reliance on speed of motor response. Analysis indicated no significant difference in processing speed between individuals with PD and controls, using this measure. A number of previous studies within which an alteration in information processing speed in PD has been observed and discussed have utilised a semantic priming task (e.g., Angwin et al., 2005). The findings here could suggest, therefore, that whilst a delay in semantic processing may present in PD, speed of visual processing may be less vulnerable.

Summary – Cognitive Profile

Cognitive processing was found to be unimpaired in the individuals with PD involved in this study, across each individual measure. Although not directly comparable as the combination of cognitive abilities under investigation within this study is not identical to that of previous studies, this study is not the first to report such a finding, with Roberts and Post (2018) similarly finding no difference in performance across any cognitive measure in a group of PD participants without dementia. As was outlined in the discussion for each individual cognitive ability, it seems likely that differences between findings reported here and those seen in the current literature are reflective, at least in part, of subtle difference between the tasks utilised. This in itself presents useful information regarding the nature of the cognitive alteration in PD, which may be worthy of consideration in future studies.

Summary – General Linguistic and Cognitive Profile

With the exception of sentence comprehension, there was no difference in the pattern of performance in any of the individual measures of cognitive and language ability between individuals with PD and controls. Attention will now turn to the first experimental research question, concerned with the influence of action and grammatical complexity on verb production in PD.

4 The influence of a verb's grammatical complexity and action level on verb production at both a single word and sentence level in Parkinson's Disease

4.1 Introduction

This chapter outlines the investigation designed to explore the influence of a verb's grammatical complexity on production in Parkinson's Disease (PD), and how this might interact with the verb's action meaning at both a single word and sentence level (Research Question 1). A reminder of the research question and component sub-questions guiding the investigation – within the context of the overall study – are presented in Figure 13.

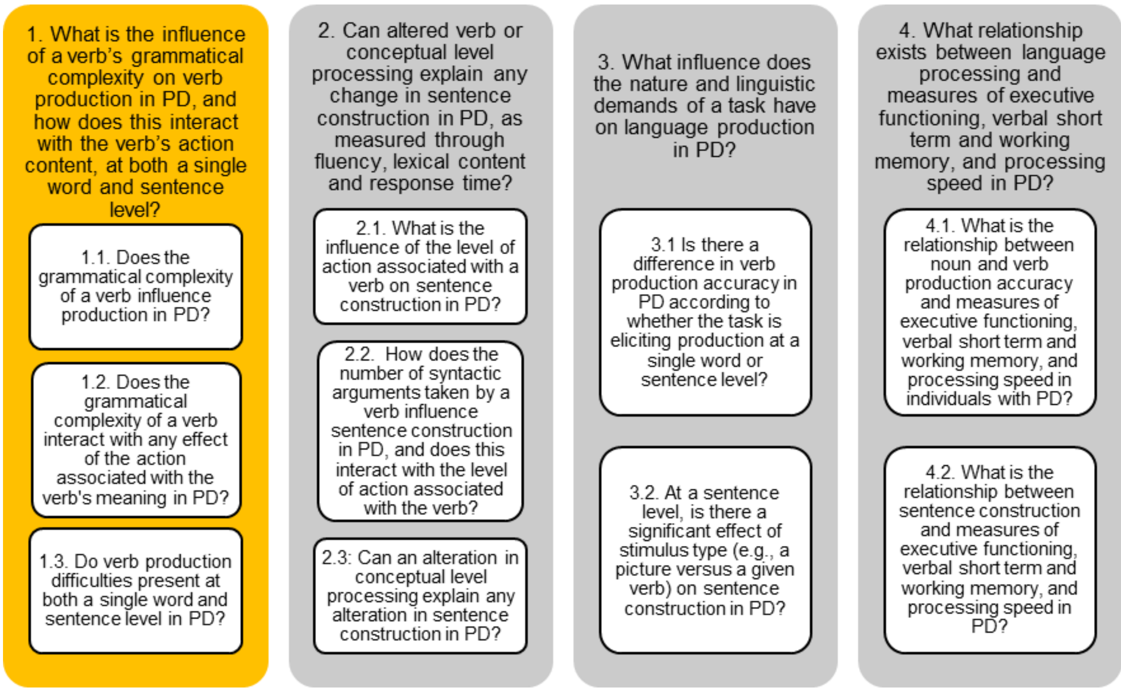


Figure 13. Research questions and sub-questions: focus on Research Question 1

Three aspects were under consideration: how the grammatical complexity of a verb influenced production in PD; in what way this interacted with any effect of the action associated with the verb's meaning on production; and whether verb production difficulties presented at a sentence as well as a single word level in PD. Grammatical complexity was considered along two lines: the number of syntactic arguments taken by the verb (transitivity) and the complexity of the required structure of those arguments.

From findings within the current literature (e.g., Bocanegra et al., 2017; Herrera, Rodriguez-Ferreiro, et al., 2012), it was predicted that verbs with a high level of action associated with their meaning would be impacted upon by PD. No studies to date have looked at the effect of grammatical complexity on verb production in PD – as measured through either the number of arguments taken, or the complexity of the structure of those arguments. Utilising information from the aphasia literature (e.g., Caley et al., 2017; Thompson, 2003) it was predicted that individuals with PD would display increased difficulty as the grammatical complexity of the verb increased; i.e., as the number of syntactic arguments taken by the verb increased, or when the verb required movement of a sentence element from its base position. Further, it was predicted that this effect would interact with the verb's meaning, such that high action verbs which can take up to three syntactic arguments would prove the most difficult. This same pattern was expected to be seen within both a single word and sentence context. No effect of either action, or grammatical complexity, on verb production was expected in the control group. A reminder of the hypothesis accompanying each sub-question is provided below:

RQ 1.1. Does the grammatical complexity of a verb influence production in PD?

> *Hypothesis: The production of verbs which are more grammatically complex, either in relation to the number of syntactic arguments they take or the structure of those arguments, will be altered in PD. No effect of grammatical complexity on production will be seen in the control group.*

RQ 1.2. Does the grammatical complexity of a verb interact with any effect of the action associated with the verb's meaning in PD?

> *Hypothesis: An interaction between action and the number of syntactic arguments that can be taken by the verb will present in PD, such that the retrieval of high action, grammatically complex verbs will be impaired. No effect of action, grammatical complexity or interaction will be seen in the control group.*

RQ 1.3. Do verb production difficulties present at both a single word and sentence level in PD?

> *Hypothesis: Verb production difficulties will be evident at both a single word and sentence level in PD.*

To conduct the analyses, data gained from three tasks was utilised (see Section 4.2):

1. A verb naming task assessing the influence of action and the number of syntactic arguments taken by the verb on production at a single word level
2. A sentence production task once again assessing the influence of action and the number of syntactic arguments taken by the verb on production, but at a sentence level

3. An ergative verb sentence production task, looking purely at the effect of the complexity of a verb's argument structure on production, at a sentence level

Results relating to performance within each task are presented in turn, followed by a brief summary of the salient points from each analysis (Section 4.3). The chapter closes with an overall discussion of the findings, in relation to hypotheses being tested and with reference to the current literature (Section 4.4).

4.2 Method

A mixed factorial design was adopted to explore each sub-question. In all analyses, participant group (i.e., PD and control) constituted the between-subjects factor. The nature and number of within-subjects factors varied between analyses. In some, grammatical complexity formed the sole within-subjects factor. In others, two within-subjects factors were included: action and grammatical complexity.

4.2.1 Verb Naming Task

As previously mentioned in Section 3.2.4, one multi-purpose verb naming task was utilised within this study. The first purpose of the verb naming task was to establish whether a selective verb deficit was evident in the PD group, through comparison with performance in a noun naming task (see Section 3.3.4 for the results of that analysis). The second purpose – which will now be reported – was to explore the effect of action semantics and the number of syntactic arguments taken by the verb on verb production at a single word level. To allow for such analysis, the verbs used within the task were categorised according to the level of action associated with their meaning and the number of syntactic arguments taken. Full detail regarding formulation of these categories will now be provided.

Materials

The 56 target verbs were divided according to the two factors of interest: action (high vs low action, with 28 verbs per level) and the number of syntactic arguments taken (14 intransitive verbs taking one argument; 15 transitive optional verbs taking one or two arguments; 13 transitive verbs taking two arguments; 14 ditransitive optional verbs taking up to three arguments[13]). This led to the formation of eight verb conditions, as illustrated in Figure 14. The full word list and additional details pertaining to its formation are provided in Appendix J.

	Intransitive (1 argument)	**Transitive Optional (1 or 2 arguments)**	**Transitive (2 arguments)**	**Ditransitive Optional (up to 3 arguments)**
Low	Intransitive, low action – *e.g., sunbathe*	Transitive optional, low action – *e.g., wait*	Transitive, low action – *e.g., ignore*	Ditransitive optional, low action – *e.g., prescribe*
High	Intransitive, high action – *e.g., collide*	Transitive optional, high action – *e.g., clap*	Transitive, high action – *e.g., mow*	Ditransitive optional, high action – *e.g., throw*

Figure 14. Verb conditions, according to action and the number of syntactic arguments taken by the verb (transitivity)

Transitivity (i.e., the number of syntactic arguments taken by the verb) was established using dictionary definition. As far as was possible, verbs which had two

[13] For a full description of each verb category, see the Linguistic Glossary (p. 181).

or more contrasting meanings were excluded. Additionally, verbs which could take sentential complements (e.g., ‘pray’) were avoided, however it was necessary to include some unaccusative verbs within the intransitive grouping (see Appendix J). Action ratings were established through asking a group of students and staff (n = 33) at the University of Strathclyde to rate the level of action they associated with each word’s meaning, on a scale of 1-5. Because responses within which a small number of words had not been rated were included, the number of ratings varied per word (see Appendix K). The survey was conducted via Qualtrics, Provo, UT (accessed via https://www.qualtrics.com).

In line with the spread of the data, verbs with a median rating of ‘1’ and ‘2 were deemed to be low action, and verbs with a median rating of ‘3’, ‘4’ or ‘5’ deemed to be high action. As such, a significant difference in median action score was evident between the ‘low’ and ‘high’ action verbs in all transitivity conditions (Intransitive group: U = 49.0, p = .001; Transitive Optional group: U = 56.0, p = .001; Transitive group: U = 42.0, p = .001; Ditransitive Optional group: U = 49.0, p = .001). Median action scores in both the low, $\chi^2(3) = 1.14$, p = .767, and high, $\chi^2(3) = 3.63$, p = .305, action conditions were matched according to syntactic argument condition. Verbs in the low and high action condition were additionally matched for frequency, U = 395, p = .967, age of acquisition (AoA), U = 356, p = .555, concreteness, U = 439, p = .441, word length, U = 392, p = 1.00 and the number of orthographic, U = 425, p = .590, and phonological neighbours, U = 362, p = .615.

Due to the restrictive nature of the groupings it was not possible to match all eight of the action-syntactic argument conditions according to the constituent words’ characteristics. All groups were matched[11] for concreteness, $\chi^2(7) = 3.34$, p = .852, length, $\chi^2(7) = 9.18$, p = .240, and orthographic neighbours, $\chi^2(7) = 13.1$, p = .071, but analyses suggested that not all were matched for frequency, $\chi^2(7) = 16.4$, p =

.022, AoA, $\chi^2(7) = 15.8$, $p = .027$, and phonological neighbours (excluding homophones), $\chi^2(7) = 17.6$, $p = .014$. For these latter comparisons, Dunn's pairwise tests were conducted to establish between which groups the significant difference lay. For both frequency and AoA however, comparisons between the pairs were all non-significant. For phonological neighbours, pairwise comparisons revealed scores in the transitive low action group to be significantly lower than those in the ditransitive optional low action group ($p = .013$). Word retrieval has been shown to be positively influenced by the number of phonologically similar neighbours the word has; such that words with a higher number of phonological neighbours are easier to retrieve (Mirman, Kittredge, & Dell, 2010). There is the potential therefore that verbs in the ditransitive optional, low action group may be advantaged as compared with the transitive low action group.

A description of the corresponding picture stimuli is provided in Section 3.2.4. The picture stimuli were matched for visual complexity across all conditions, $F(7, 55) = 0.91$, $p = .510$.

Procedure and Scoring

For full detail regarding how the task was run and scored, see Section 3.2.4. To summarise, participants were shown a picture in the centre of a laptop screen and asked to name the depicted action. Stimuli were delivered across two equal task blocks. Responses were marked as correct if the target verb was used. Corrected answers (i.e., corrections made immediately after an initial answer had been given) were accepted and marked as correct. RT was only calculated for correct (*not* including corrected) answers and the consequent data trimmed using an absolute cut-off. Thirty one responses (2.22% of total correct responses) were excluded due to exceeding the upper cut-off of 5000ms.

4.2.2 Sentence Production Task

To assess the influence of action and the number of syntactic arguments (transitivity) taken by the verb on verb production at a sentence level, a sentence production task was designed, using the same stimuli utilised within the single word task. As with the verb naming task just described, the sentence production task had a dual purpose. It was designed both – again through different stages of analysis – to provide information about the retrieval of verbs containing specific grammatical and action characteristics at a sentence level (as described in the following paragraphs), but also to gain an understanding of the influence of the level of action associated with a verb's meaning on separate measures of sentence construction (see Section 5.2.1). First, as outlined here, responses from the task were analysed to investigate verb production in a sentence context.

Materials

The same 56 verbs and corresponding picture stimuli utilised within the verb naming task (see Section 4.2.1) were used within the sentence production task. Stimuli were presented via a laptop, scaled to approximately 425 x 284 pixels (approximately 8.6cm x 5.7cm), with a sentence starter (e.g., 'the man is…'), provided underneath the picture (see Figure 15 for an example).

The woman is…

Figure 15. Example stimulus used within the sentence production task.

Procedure and Scoring

Participants were shown each stimulus in turn (see Figure 16) and asked to create a sentence describing the action that they saw taking place in the picture, beginning with the sentence starter provided. It was requested that individuals described the action as specifically as they could, using a full sentence. Individuals were asked to provide their answer as soon they could, once they had thought of it. The stimuli were re-randomised for this task, to reduce priming effects, and presented in two blocks of equal length.

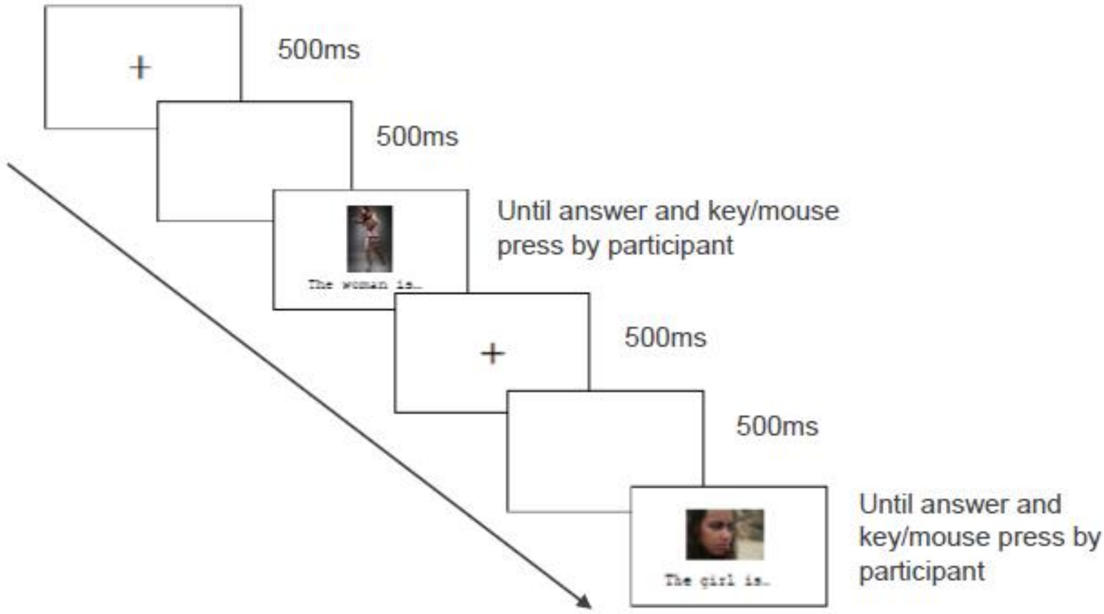


Figure 16. Procedure for Sentence Production Task.

Verb tokens were marked as correct if the target verb had been used as the main verb within either an independent or dependent clause. Corrected answers were accepted. One point was awarded for each correct answer and 0 points for any incorrect answer. In any instances where an individual had provided more than one sentence or optional predicates (e.g., ‘the man is running or tripping’), if either contained the target verb that sentence was taken as an individual’s answer. If neither sentence contained the target, the first sentence was taken as an individual’s answer, *unless* the sentences were conjoined by an ‘or’, in which case the second sentence was taken. A percentage correct score was calculated for each participant, in each condition.

4.2.3 Ergative Verb Sentence Production Task

This task was designed to assess the effect of a different form of grammatical complexity on verb processing in a sentence context. In contrast to the previous two tasks outlined, here grammatical complexity related not to the number of arguments required by the verb but the required structure of those arguments. This was explored using ergative verbs: ambitransitive verbs which form sentences within which the subject position can be taken either by the agent or the theme, as exemplified below (Bastiaanse & van Zonneveld, 2005):

Unaccusative reading: ‘the bell is ringing’

Transitive reading: ‘the woman is ringing the bell’

Because only the unaccusative reading requires movement of the theme, comparing sentence accuracy between the two readings gives a useful insight into which aspect of a verb’s grammatical complexity, i.e., the number of arguments, or the necessitation of movement of a sentence element from its base position, has the greater impact in PD (Bastiaanse & van Zonneveld, 2005).

Materials

Six ergative verbs were chosen for the task; *rip, burst, smash, dissolve, burn and melt.* Twelve picture stimuli, depicting both readings of each verb, were created. For all transitive readings, a person was shown carrying out the action. The picture stimuli were presented via a laptop, scaled to approximately 425 x 284 pixels (approximately 8.6cm x 5.7cm), with the target verb presented underneath (see Figure 17; *Transitive Target: ‘the woman/chef is melting the chocolate’; Unaccusative Target: ‘the chocolate is melting’*).

Transitive	Unaccusative
	
Melt	Melt

Figure 17. Picture stimuli in the ergative verb subtask, according to verb reading.

Procedure and Scoring

The task paradigm was largely analogous to that employed within the previously described sentence production task (see Figure 16). Stimuli were always presented in consecutive verb pairs (i.e., the two readings of 'melt', for example, were presented sequentially, one after the other) however the order was randomised such that for half of the verbs the transitive sentence was elicited first, and in the other half the reverse pattern adopted.

Individuals were asked to describe what was happening in the picture, using the verb printed underneath the picture. It was clarified that the verb could be used in any tense. Sentences were marked as correct if the verb had been used in the target reading, i.e., the target verb had been used and the thematic roles were in the correct position in the syntactic frame, for the target reading. One point was awarded for each correct answer, and points summed to create each participant's score, per condition. Corrected answers were accepted.

4.3 Results

4.3.1 The effect of action and the number of syntactic arguments taken by the verb on production at a single word level

For both accuracy and RT, a 2 (group) x 2 (action) x 4 (transitivity) mixed factorial ANOVA was conducted to assess the effect of action and the number of syntactic arguments taken by the verb (transitivity) on single word verb naming in individuals with PD, as compared with controls. Due to missing data points, three participants (one PD and two controls) were excluded from any analysis involving RT data which required list wise deletion. Consequently, for any such comparisons, n = 38.

It was mentioned in the previous chapter (see Section 3.2.4) that examination of the raw data from the verb naming task had highlighted presence of greater variability of responses to some stimuli than to others. To address the potential confound of stimulus-led variability, the dataset was adjusted through the removal of stimuli for which the modal response from control participants was not the target (for full detail of this procedure, see Section 3.3.3). The ten verbs removed from the dataset were distributed as follows: one was removed from the low action, intransitive condition ('chat'), four from the high action, intransitive condition ('collide', 'sob', 'tiptoe' and 'stumble'), one from the high action, transitive optional condition ('swallow'), two from the low action, transitive condition ('sprinkle' and unlock') and two from the high action, transitive condition ('bury', 'unload'). The adjusted dataset (containing 46 verbs) was used for this and all further analyses. The data are presented in Table 17.

Table 17.

Mean (SD) and median (IQR) accuracy and RT scores in the verb naming task, as a function of group, action and the number of syntactic arguments taken by the verb (transitivity)

		PD		Control	
		Low	High	Low	High
		Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
Accuracy (% Correct)	Intransitive	71.9 (16.9)	91.7 (19.2)	72.7 (16.6)	97.3 (9.24)
		66.7 (29.2)	*100 (0.00)*	*83.4 (16.7)*	*100 (0.00)*
	Transitive Optional	64.1 (18.2)	75.0 (16.1)	78.0 (13.6)	82.7 (15.6)
		62.5 (21.9)	*66.7 (16.7)*	*75.0 (12.5)*	*83.3 (33.3)*
	Transitive	56.3 (23.3)	62.5 (26.2)	61.0 (28.0)	64.8 (20.6)
		62.5 (25.0)	*60.0 (35.0)*	*75.0 (25.0)*	*60.0 (50.0)*
	Ditransitive Optional	75.0 (14.3)	59.8 (22.3)	78.3 (15.5)	65.1 (18.0)
		71.4 (14.3)	*57.1 (39.3)*	*85.7 (14.3)*	*71.4 (28.6)*
RT (ms)	Intransitive	1690 (612)	1237 (393)	1439 (412)	1156 (345)
		1500 (757)	*1264 (544)*	*1345 (649)*	*1048 (456)*
	Transitive Optional	1600 (407)	1773 (423)	1596 (423)	1440 (434)
		1553 (706)	*1928 (724)*	*1588 (564)*	*1324 (426)*
	Transitive	1952 (301)	1504 (298)	1760 (342)	1450 (533)
		1928 (394)	*1536 (399)*	*1709 (428)*	*1298 (537)*
	Ditransitive Optional	1764 (525)	2079 (640)	1583 (376)	1883 (550)
		1675 (878)	*1863 (1091)*	*1558 (434)*	*1780 (655)*

For accuracy, significant main effects of action, $F(1,39) = 8.31$, $MSE = 256$, $p = .006$, $\eta_p^2 = .18$, and transitivity, $F(2.10, 81.8) = 22.9$, $MSE = 425$, $p < .001$, $\eta_p^2 = .37$, were evident. An interaction was additionally evident between these two variables, $F(2.50, 97.6) = 14.9$, $MSE = 118$, $p < .001$, $\eta_p^2 = .28$ (see Figure 18). All other main effects and interactions were non-significant (all $p > .12$).

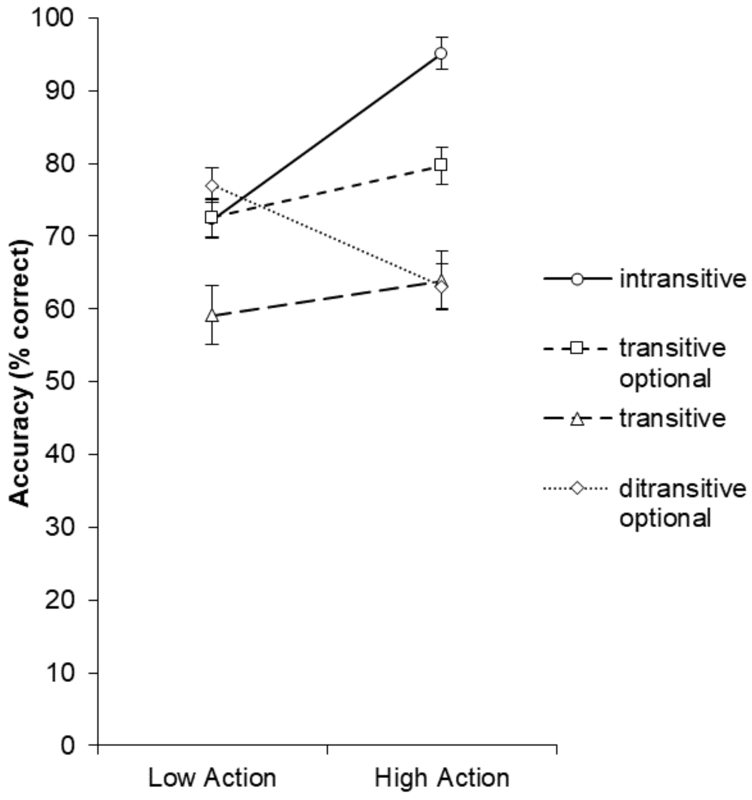


Figure 18. Interaction between the effect of action and the number of syntactic arguments taken by the verb (transitivity) on verb production accuracy, collapsed across group

Collapsed across group, follow up t-tests (adjusted α = .0125) revealed action to have a significant effect in the intransitive, $t(40) = -7.71$, $p < .001$, $d = 1.49$, and ditransitive optional conditions, $t(40) = 3.86$, $p < .001$, $d = 0.79$. The direction of the effect was opposed in the two grammatical categories. Whilst in the intransitive condition, the majority of individuals received higher scores in the high action condition ($M_{Low} = 72.4$, $SD_{Low} = 16.5$; $M_{High} = 95.1$, $SD_{High} = 14.1$) in the ditransitive optional condition higher scores were evident in the low action condition ($M_{Low} = 77.0$, $SD_{Low} = 14.9$; $M_{High} = 63.1$, $SD_{High} = 19.7$). No other comparisons were significant (all $p > .05$). Non-parametric analyses – conducted because both the data for the ANOVA and data for the intransitive and ditransitive optional follow up comparisons failed the assumption of parametric analysis – corroborated these findings in both instances (intransitive: $z = 5.03$, $p < .001$, $r = 0.79$; ditransitive: $z = 2.74$, $p = .006$, $r = 0.43$).

Also considered was whether the performance of the sub-group of six individuals with PD who showed altered performance within the noun and/or the verb production task at an individual level (see Section 3.3.5) differed from that of the rest of the group. Exploration showed the patterns to be largely parallel to those seen at the whole group level (see Figure 18). The most noticeable divergence was in the ditransitive optional condition, with three of the subgroup showing equal scores in both action conditions. Importantly, where divergence from the group level pattern was apparent, it was not confined to this sub-group of participants but also seen in the broader PD group. With regard to the pattern seen in the ditransitive optional condition, as just referred to, no obvious grouping factors presented themselves; the sex, age, education and disease duration of individuals who showed the pattern were all mixed. And, indeed, the same was true when including control participants who showed the same pattern. In other words, there are no obvious signs as to why this pattern may have presented in these participants.

For response time (RT), significant main effects of transitivity, $F(3, 108) = 22.4$, $MSE = 110923$, $p < .001$, $\eta_p^2 = .38$, and action, $F(3, 108) = 6.51$, $MSE = 129355$, $p = .015$, $\eta_p^2 = .15$ were evident. Significant interactions existed between action and transitivity, $F(3, 108) = 22.7$, $MSE = 86977$, $p < .001$, $\eta_p^2 = .39$, and between action, transitivity and group, $F(3, 108) = 2.71$, $MSE = 86977$, $p = .048$, $\eta_p^2 = .070$. Two (one per group), two-way repeated measures ANOVAs showed a significant main effect of action in the PD group, $F(1, 14) = 5.95$, $MSE = 53670$, $p = .029$, $\eta_p^2 = .30$ (no significant main effect of action was seen in the control group, $p = .085$). In both the

PD and control group a significant main effect of transitivity was evident, PD: $F(2.01, 28.2) = 7.98$, $MSE = 197784$, $p = .002$, $\eta_p^2 = .36$; Control: $F(3, 66) = 15.9$, $MSE = 97008$, $p < .001$, $\eta_p^2 = .42$. Further, a significant interaction between action and transitivity was evidenced in both groups, PD: $F(3, 42) = 16.6$, $MSE = 74106$, $p < .001$, $\eta_p^2 = .54$; Control group: $F(2.19, 46.6) = 9.69$, $MSE = 134923$, $p < .001$, $\eta_p^2 = .31$ (see Figure 19).

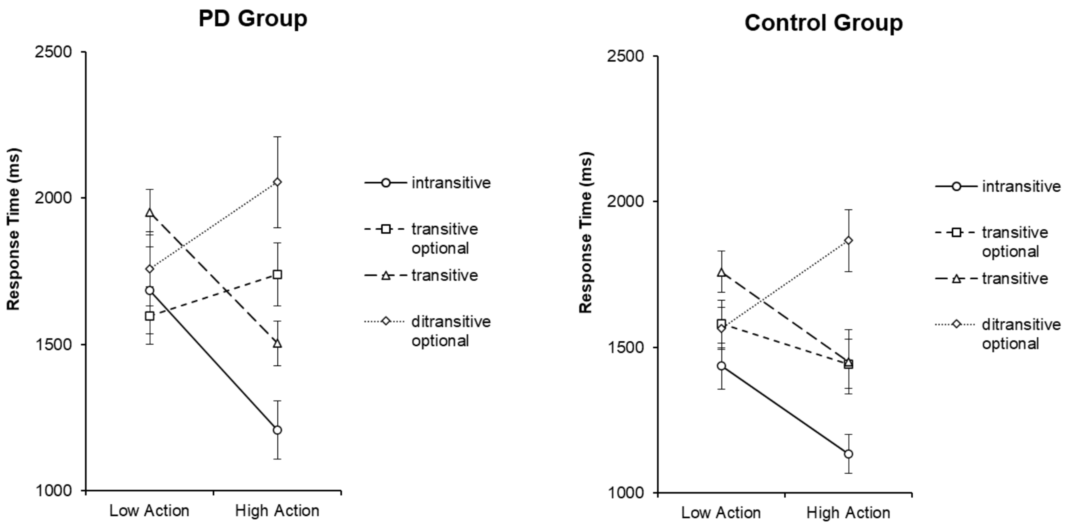


Figure 19. Interaction between the effect of action and the number of syntactic arguments taken (transitivity) on verb naming RT, according to group

In the PD group, follow up comparisons (adjusted $\alpha = .0125$) revealed a significant effect of action at two levels of transitivity: intransitive, $t(15) = 5.07$, $p < .001$, $d = 0.95$ and transitive, $t(14) = 5.10$, $p < .001$, $d = 1.50$. The direction of the effect was the same in both groups, with stimuli responded to significantly faster in the high action condition (intransitive: $M_{Low} = 1685$ms, $SD_{Low} = 592$ms; $M_{High} = 1208$ms, $SD_{High} = 397$ms; transitive: $M_{Low} = 1952$ms, $SD_{Low} = 301$ms; $M_{High} = 1504$ms, $SD_{High} =$

298ms. No other comparisons were significant (all $p > .018$). Further exploration of the data indicated a small number of instances in which the pattern shown by the subgroup of individuals whose scores in either the noun and/or verb production task was 2 *SD*s away from the mean diverged from the pattern shown across the whole group. This was primarily seen in the transitive optional and ditransitive optional conditions and, again, in both instances was also seen in a small number of other PD participants. In other words, whilst some differences in pattern were seen, these were not unique to the altered noun/verb performance subgroup and, within the group of participants who showed a different pattern of performance, no obvious identifying factors were evident.

In slight contrast, in the control group the effect of action was significant in the intransitive, $t(24) = 3.85$, $p = .001$, $d = 0.82$, and ditransitive optional conditions, $t(24) = -3.38$, $p = .003$, $d = -0.66$. The pattern seen in the intransitive condition followed that shown in the PD group, with high action appearing to have a faciliatory effect on RT (M_{Low} = 1437ms, SD_{Low} = 396ms; M_{High} = 1134ms, SD_{High} = 339ms). The reverse pattern was evident in the ditransitive optional condition however, with higher action having a detrimental effect (M_{Low} = 1565ms, SD_{Low} = 366ms; M_{High} = 1866ms, SD_{High} = 533ms). No other comparisons were significant (all $p > .027$).

Due to the data for the ANOVA and follow up comparisons failing the assumptions of the test, non-parametric Sign tests were additionally run to confirm the influence of action in the intransitive ($z = -3.75$, $p < .001$, $r = 0.94$) and transitive condition ($z = -3.10$, $p = .001$, $r = 0.80$) in the PD group, and in the intransitive ($z = -4.00$, $p < .001$, $r = 0.80$), and ditransitive optional conditions ($z = 2.80$, $p = .004$, $r = 0.56$) in the control group. In all instances, findings from these analyses corroborated those from the parametric analysis.

Summary of Results

No main effect of group on verb production accuracy was evident and group did not interact significantly with either action or/and transitivity. There was however, collapsed across group, a significant interaction evident between action and transitivity. The effect of action was evident within the intransitive and ditransitive optional conditions, in opposing directions. In the intransitive condition higher action appeared to be facilitatory, with the reverse effect seen in the ditransitive optional condition.

When assessing RT, a significant three-way interaction between group, action and transitivity was evident. In both the PD and control group, action was found to have a significant effect within the intransitive condition; the direction of which mirrored that seen in the accuracy measure (i.e., in both groups responses to high action stimuli were given more quickly). From here however the groups diverged. In the PD group, a significant effect of action - mirroring that seen in intransitive condition - was seen in the transitive condition. In the control group however, the effect of action was also found to be significant in the ditransitive optional group, the direction of which again mirrored that seen in the accuracy measure (i.e., low action stimuli were responded to more quickly in this condition).

The group of individuals with PD who, at an individual level, showed impaired performance within either the noun and/or verb task did not appear to be differentially influenced by the characteristics of the verb under investigation here. Whilst patterns of individual performance did vary from the group pattern in some instances, this was not confined to individuals who had received scores 2 *SD*s away from the mean in the noun and/or verb tasks, and no obvious common characteristics within groups of individuals who showed these patterns were evident.

4.3.2 The effect of action and the number of syntactic arguments taken by the verb on production at a sentence level

The same 2 (group) x 2 (action) x 4 (transitivity) mixed factorial ANOVA was utilised to investigate the effect of action and the number of syntactic arguments (transitivity) on verb production accuracy (percentage correct score) at a sentence level.

As with the verb naming task, examination of the raw data from the sentence production task revealed variability of responses to some stimuli to be greater than others. The same adjustment was therefore conducted, through removing from the dataset any stimuli for which the modal response from control participants was not the target (for full detail of this procedure, see Section 3.3.3). This led to the removal of 11 verbs from the dataset: one from the low action intransitive condition ('scowl'), four from the high action, intransitive condition ('stumble', 'collide', 'tiptoe', 'sob'), one from the transitive optional, low action condition ('donate'), one from the high action, transitive optional condition ('swallow'), two from the low action, transitive condition ('recycle', 'sprinkle') and two from the high action, transitive condition ('extinguish', 'unload'). The adjusted dataset, equalling 45 verbs, was used for this and any further analyses. The data, according to condition, are provided in Table 18.

Table 18.

Mean (SD) and median (IQR) verb accuracy scores in the sentence production task, as a function of group, action and *the number of syntactic arguments taken by the verb (transitivity)*

		PD		Control	
		Low	High	Low	High
		Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
Accuracy (% Correct)	Intransitive	65.6 (12.9)	91.7 (14.9)	72.7 (16.6)	94.7 (12.5)
		66.7 (29.2)	*100 (25.0)*	*66.7 (16.7)*	*100 (0.00)*
	Transitive Optional	61.6 (20.7)	77.1 (14.8)	62.9 (19.3)	82.7 (14.8)
		64.3 (28.6)	*83.3 (16.7)*	*71.4 (28.6)*	*83.3 (33.3)*
	Transitive	43.8 (21.4)	47.5 (20.5)	51.0 (24.5)	56.0 (28.9)
		37.5 (43.8)	*60.0 (20.0)*	*50.0 (50.0)*	*60.0 (40.0)*
	Ditransitive Optional	73.2 (13.7)	64.3 (18.1)	72.6 (17.5)	56.0 (21.8)
		71.4 (28.6)	*71.4 (35.7)*	*71.4 (28.6)*	*57.1 (28.6)*

Analysis revealed a significant main effect of action, $F(1,39) = 21.1$, $MSE = 256$ $p < .001$, $\eta_p^2 = .35$, and transitivity, $F(2.45, 95.7) = 43.5$, $MSE = 381$, $p < .001$, $\eta_p^2 = .53$, in addition to a significant interaction between these variables, $F(3, 117) = 15.0$, $MSE = 343$, $p < .001$, $\eta_p^2 = .28$ (see Figure 20). No other interactions or main effects were significant (all $p > .17$).

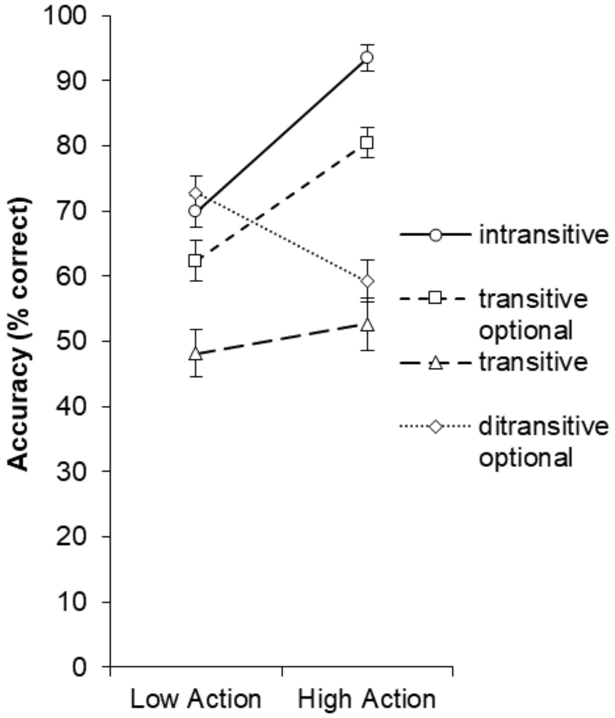


Figure 20. Interaction between the effect of action and the number of syntactic arguments taken (transitivity) on verb production accuracy in a sentence context, collapsed across group

Collapsed across groups, t-tests (adjusted α = .0125) revealed action to have a significant effect within the intransitive, $t(40) = -8.11$, $p < .001$, $d = 1.63$, transitive optional, $t(40) = -4.9$, $p < .001$, $d = 1.04$, and ditransitive optional, $t(40) = 3.49$, $p = .001$, $d = 0.74$, conditions (for the transitive condition comparison, $p = .365$). The effect of action varied across grammatical conditions. In both the intransitive ($M_{\text{Low}} = 69.9$, $SD_{\text{Low}} = 15.5$; $M_{\text{High}} = 93.5$, $SD_{\text{High}} = 13.4$) and transitive optional conditions ($M_{\text{Low}} = 62.4$, $SD_{\text{Low}} = 19.6$; $M_{\text{High}} = 80.5$, $SD_{High} = 14.9$) accuracy was greater in the high action condition, whilst the reverse pattern was evident in the ditransitive optional condition ($M_{\text{Low}} = 72.8$, $SD_{\text{Low}} = 15.9$; $M_{\text{High}} = 59.2$, $SD_{\text{High}} = 20.6$).

Neither data for the ANOVA, or data for the intransitive or ditransitive optional within-subjects follow up comparisons met all the assumptions of parametric analysis, and non-parametric Sign tests consequently run. Findings corroborated the main effect of action in the intransitive condition, $z = 5.22$, $p < .001$, $r = 0.82$ but did not support the presence of a significant effect of action in the ditransitive optional condition, $z = -1.95$, $p = .052$, $r = 0.30$. Additional data exploration indicated that whilst the pattern of some individuals who showed performance in the noun and/or verb tasks which was 2 *SD*s below the mean did differ from the overall group-level pattern, the number of instances were small. Furthermore, as with the single word verb task, these differing patterns were not confined to this sub-group and extended both to other individuals with PD and control participants.

Summary of Results

Group was not found to have a significant main effect on verb naming accuracy at a sentence level, nor was a significant interaction between group and action or/and transitivity evidenced. Collapsed across group however, action and transitivity were shown to have a significant, interacting effect on verb production accuracy in a sentence context. Follow up comparisons revealed the significant effect of action to reside in the intransitive and transitive optional conditions with, in both conditions, high action leading to greater response accuracy. The additional indicated effect of action in the ditransitive optional condition was not corroborated by non-parametric analysis.

4.3.3 The effect of the complexity of a verb's required argument structure on production, at a sentence level

A 2 (group) x 2 (verb reading) mixed factorial ANOVA was conducted to establish the effect of the complexity of a verb's required argument structure – as measured through ergative verb reading – on sentence accuracy, per group. One control participant was excluded due to having misunderstood the task, leaving 40 participants. Data are presented in Table 19.

Table 19.

Ergative verb production accuracy as a function of verb reading and group

	PD	Control
	Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Unaccusative	2.00 (1.21) *2.00 (2.00)*	2.29 (1.00) *2.00 (1.00)*
Transitive	3.44 (1.21) *3.50 (1.00)*	3.83 (0.70) *4.00 (1.00)*

A significant main effect of verb reading was evident, $F(1,38) = 34.5$, $MSE = 1.24$, $p < .001$, $\eta_p^2 = .48$. Collapsed across groups, accuracy scores were significantly higher in the transitive (*estimated marginal mean [EMM]* = 3.64, *SE* = 0.15) as compared with the unaccusative reading (*EMM* = 2.15, *SE* = 0.17). No other main effects or interactions were significant (all $p > .10$). Data for the ANOVA violated the assumption of normality and homogeneity of variances; thus, data for the analysis indicating a significant main effect of verb reading was consequently checked. Data for this within-subjects comparison failed the assumption of normality. Findings from a non-parametric Sign test supported the significant effect of verb reading, $z = 4.27$, $p < .001$, $r = 0.68$.

Further exploration indicated this pattern, i.e., scores being higher in the transitive reading, to be present in the vast majority of participants. Instances where this was not the case included, but was not exclusive to, individuals with PD who had a score 2 *SD*s below the mean in either the noun and/or verb task. Again, within this group, no obvious unifying factors presented; age, sex and years of education were all mixed, as well as years since diagnosis in PD participants.

In summary, a significant main effect of verb reading was indicated, with unaccusative readings – i.e., those that required movement of a sentence element – leading to reduced accuracy. No difference in the pattern of performance between individuals with PD and controls was evident.

4.4 Discussion

The aim of this investigation was to explore the influence of two variables – the action associated with a verb's meaning, and the verb's grammatical complexity – on verb production in PD, in both a single word and sentence context. Results from the analyses are discussed and considered in relation to the three factors outlined in the theoretical background which may be underpinning the verb alteration seen in PD: the influence of semantics, the influence of selection and control mechanisms and the influence of grammatical word class. The discussion is divided according to production context, with consideration of findings from production at a single word level first presented.

4.4.1 Verb Production at a Single Word Level

In contrast to previous findings reported within the literature (e.g., Bocanegra et al., 2017; Herrera, Rodríguez-Ferreiro, & Cuetos, 2012), results from this study offer little empirical support for the semantic hypothesis. For such a hypothesis to be confirmed, the need for difference in performance according to verb type (e.g., between high action and low action verbs) has been outlined (da Silva et al., 2014). Whilst in this study the degree of action associated with the verb's meaning was shown to have a significant effect on verb production accuracy, this effect did not interact with group. Thus, whilst an effect of action was seen, its influence was not different or significantly greater in the PD group, as compared with controls.

Similarly, the findings offer little empirical support for the hypotheses concerned with selection demands, or factors intrinsically linked to the grammatical word class of 'verb'. Whilst the number of syntactic arguments taken by the verb (transitivity) was found to have a significant effect on verb production, again this effect did not interact with group. Thus, whilst this finding would indicate that verb naming accuracy was influenced by factors intrinsically linked to the grammatical word class of 'verb' – and potentially by selection demands, depending on whether one or more sentence frames could be taken – this effect was not found to differ, nor appear to a greater degree, in individuals with PD, as compared with controls.

A significant interaction between action and transitivity was further seen, such that action was found to have a significant effect only at certain transitivity levels. When considering verb production accuracy, this did not interact with group; in other words, the same pattern was shown in individuals with PD and controls. A slightly different outcome was seen when RT was considered however, with the transitivity conditions within which action had a significant effect found to vary slightly between individuals with PD and controls. These findings will be considered in turn.

Accuracy

The fact that, in both groups, action had the opposite effect within different transitivity conditions is interesting to consider. Caution does need to be extended when interpreting these results, as the number of tokens per condition – particularly in the intransitive condition – were small. Nonetheless, it suggests that the linguistic characteristics of the words employed may affect the impact of a word's action on production, and therefore influence results if not controlled. Results suggested that higher action had a facilitatory effect within verbs which could take only one sentence frame and take one argument (intransitive condition), but a detrimental one in words which can take multiple sentence frames and up to three arguments (ditransitive optional).

How this finding is interpreted depends on whether the semantic richness which accompanies more grammatically complex verbs (as measured through the number of arguments taken) appears to be facilitating retrieval (e.g., Rodríguez-Ferreiro et al., 2014) or whether the increased demands that more grammatically complex verbs place on the grammatical encoder is making retrieval more difficult (Bastiaanse et al., 2016). Findings from this study would suggest the latter, with post-hoc analysis showing accuracy to decrease as the number of syntactic arguments taken by the verb increased (specifically, accuracy was shown to be significantly greater in the intransitive as compared with all other transitivity conditions, and significantly greater in the transitive optional condition, as compared with the transitive condition). Thus, these findings appear to suggest that, when a verb's transitivity makes it easier to retrieve (i.e., when it takes fewer syntactic arguments), a higher degree of semantic action further increases accuracy. When, however, the transitivity of the verb makes retrieval more difficult, this difficulty is exacerbated when a greater degree of action is associated with a verb's meaning, such that high action verbs show a lower degree of accuracy than low action verbs.

The fact that transitivity – irrespective of the interacting effect of action – was found to have a significant effect across all participants was not as was predicted, and stands in contrast to previously reported findings (Malyutina & Zelenkova, 2020; Thompson et al., 1997). The age of the non-brain damaged participants in Thompson et al.'s (1997) study is not known, making direct comparison difficult. It is however interesting to note that the control group in Malyutina and Zelenkova's (2020) study was younger than that of this study (age range 18-30), presenting the possibility that age is contributing to the difference in findings seen.

Similarly, it is interesting to consider why a significant effect of action was seen across all participants in this study when it has not been seen in previous studies (e.g., Herrera, Rodríguez-Ferreiro, et al., 2012). One potential explanation is that the finding reflects a confound of semantic association or, more specifically, the number of semantic associations. Whilst the characteristics of the verbs utilised within the tasks, in terms of their transitivity, were equivalent in each action condition, there is the potential that a difference existed in the number of contexts within which the high and low action verbs in each transitivity condition could occur and, by extension, a difference in the number of semantic associations. In turn, what appeared to be a facilitatory effect of action in the intransitive condition and a detrimental one in the ditransitive optional condition could potentially have reflected the fact that, in the intransitive condition, the high action verbs had more semantic associations, giving them a processing advantage over low action equivalents, whilst in the ditransitive condition, the reverse was true, leading to the opposite effect.

Even if what appeared to be an effect of action was in fact one of semantic association, a different pattern of performance would still be predicted in the PD group, as compared with controls. Whilst the effect of increased semantic associations has been suggested to be facilitatory for neurotypical individuals (Rodríguez-Ferreiro et al., 2014), with increased semantic and contextual associations may also come an increase in the number of potential meanings, from which a single one needs to be selected (Breedin et al., 1998; see also Thompson-Schill et al., 2005). Thus, one could suppose that verbs which have increased semantic associations are also going to place greater demands on executive control processes, necessary for successful selection. Given findings to suggest that selection processes may be impaired in PD (Crescentini, Mondolo, et al., 2008; Silveri et al., 2018) one would predict that any condition within which a greater number of semantic associations was present would reduce accuracy in the PD group.

The fact therefore that no difference in performance emerged between the groups could indicate either that there was no differential effect of action on verb processing in this group of individuals with PD and/or reflect the fact that the executive control processes of this group of individuals with PD was comparable to that of controls, thus leading to comparable performance. Because the number of semantic associations in each action-grammatical condition was not controlled, it is impossible to rule out the latter possibility. And, indeed, it remains possible that such a confound may also have existed in previous studies which did find a significant effect of action on verb processing in PD (Bocanegra et al., 2017), drawing into question exactly what the apparent effect of action may have been reflecting. An alternative explanation relates to the degree of action associated with the verbs utilised within this study, and the specificity of them. Evidence discussed in Section 1.2.3.2 pointed towards the ‘action’ deficit in PD being limited and specific; thus, the possibility remains that no effect of action, above that observed in the control group, was seen in PD participants because the high action verbs used within this study were not ‘high action’ enough. It was mentioned in Section 4.2.1 that, due to the spread of the data, verbs with a median rating of ‘3, 4 or ‘5’ were assigned to the high action group. This meant that verbs which fell in the middle of the action rating scale were allocated to the ‘high action’ group. This, due to the constraints placed on verb selection, was unavoidable here, but may have resulted in a ‘high’ action group which was relatively ‘low’ action. It may be that, were higher ‘high’ action verbs employed – which may have been more vulnerable to the degradation of motor information within the conceptual representation – a differential effect of action in the PD group may have been seen.

Whilst previous research has not indicated a significant relationship/correlation between UPDRS scores and verb processing (e.g., Bocanegra et al., 2017), the possibility nonetheless remains that what separated the performance of individuals with PD within this and previous studies – in relation to the influence of action, particularly – was the progression of participants' motor symptoms. The information necessary to make such a comparison is not available within this study – and, in any respect, for the purpose of such comparison the UPDRS may not be a sensitive enough measure, given the indicated specificity of the motor-linked language alteration in PD (see Section 1.2.3.2). Future studies would benefit both from collecting detailed information about PD participants’ motor functioning (such as that collected with Roberts et al.’s 2017 study) and manipulating the stimuli according to the position of the action (i.e., upper and lower limb) as well as the degree of it (i.e., high vs low action) whilst appropriately controlling the potential confound of semantic association just outlined.

Potentially important to consider, too, is the presence/absence of limb apraxia. Research would suggest the prevalence of apraxia in PD to be relatively low – ranging from 17% in Vanbellingen et al.'s (2012) study and 27% in the work of Leiguarda et al. (1997) – with it more typically associated with other Parkinsonism Syndromes (such as Progressive Supranuclear Palsy [PSP] and more particularly Corticobasal Degeneration [CBD]; Leiguarda et al., 1997; Vanbellingen et al., 2012).

Across their work, Cotelli et al. (2007, 2006), considered the effect of manipulability – as measured in relation to the involvement of fine hand movement – on action naming. The authors found different patterns of performance across different neurological conditions (including PD), which they discussed in relation to limb apraxia. Given this potential association, the possibility presents that the presence/absence of limb apraxia in PD may influence verb naming separately and/or in addition to any influence of the motor impairment core to and characteristic of PD. In turn, the possibility cannot therefore be ruled out that the difference seen in this as compared with previous studies may be partially attributable to the presence/absence of apraxia within the PD group.

The manipulability of actions was not controlled within this study, nor was apraxia tested for. This is in keeping with previous studies (e.g., Bocanegra et al., 2017; Herrera, Rodríguez-Ferreiro, et al., 2012) however such assessment certainly appears worthy of consideration in future work. This is the case particularly given that manipulation in Cotelli et al.'s (2007) study was measured in relation to the involvement of fine hand movement, and in light of the findings of Roberts et al. (2017) to indicate that upper limb verbs may be particularly vulnerable in PD. Further, the apraxia observed in Parkinsonism conditions (including PD) is typically attributed to the combination of cortical and basal ganglia pathology – such that the presence of absence of additional cortical pathology may determine the presence or absence of apraxia (Leiguarda et al., 1997). Assessing apraxia in future studies, and comparing performance in PD with other parkinsonism conditions which vary in cortical involvement, could be elucidating in teasing apart what alteration may be attributable to basal ganglia circuitry dysfunction specifically, as compared with combined cortical and basal ganglia dysfunction.

Response Time

In contrast to the analysis concerned with accuracy, a significant interaction between group, transitivity and action was seen when RT was considered. Patterns between the groups were similar, but not identical. Further, whilst the pattern seen in the control group mirrored that for accuracy – i.e., higher action was found to be facilitatory in the intransitive condition but to have a deleterious effect in the ditransitive optional condition – in the PD group, action was found to have a significant effect within the intransitive and transitive conditions with, in both instances, higher action leading to faster RTs. This finding could indicate presence of a speed/accuracy trade-off in the PD group, with slower responses to low action verbs in the transitive condition allowing for equivalent accuracy between the two action conditions. Conversely, the lack of any effect of altered RT in the ditransitive optional condition could indicate that such compensatory measures were not applied in this condition, and accuracy differences seen. That being said, the pattern of influence in the ditransitive optional condition appeared to be the same in both the PD and control group (and was approaching significance in the PD group; $p = .018$), thus both mirrored that seen in the accuracy condition. Bearing in mind the smaller sample size in the PD group, it should be considered that reduced statistical power might have been an issue here.

4.4.2 Verb Production at a Sentence Level

The pattern of findings from the analysis of verb production at a sentence level were similar but not identical to those observed at the single word level. Action was again shown to have a significant influence within the intransitive condition, however the indicated influence of action within the ditransitive condition was not supported by necessary non-parametric analysis. In contrast to production in a single word context, in a sentence context an effect of action was also seen in the transitive optional condition. In both the intransitive and transitive optional conditions, higher action was shown to have a facilitatory effect. Again, this effect was seen across the two groups.

Once again, the fact that there was no difference in the pattern of performance between individuals with PD and controls goes against that predicted. The finding that verb processing was found to be unaltered at both a single word and sentence level in the PD group could indicate the cognitive-linguistic processing demands to be the same in both conditions, and – coupled with the fact that the verb's transitivity was shown to have an effect on production at a single word level – would appear to be in line with the models of language production positing that grammatical encoding is required even at a single word level (Bastiaanse et al., 2016; cf. Vigliocco et al., 2011). It should be noted, however, that the overall cognitive demands of the task were reduced through the inclusion of a sentence starter. This, combined with the fact that the PD group within this study performed comparably to controls within all cognitive measures, may have enabled comparative verb accuracy between the tasks.

Why it was the case that, collapsed across all participants, action was shown to have a significant effect on production in different transitivity levels in a sentence production as compared with a single word context, is interesting to consider. One potential explanation is that of constraint. In the single word condition, individuals were asked to describe the action they saw taking place using one word. In contrast, in the sentence production task participants were able to talk round the action, potentially allowing for more nuanced verb choice but equally potentially reducing the chance of individuals settling on the target. It may have been the case that, in the transitive optional condition, stimuli in the low action condition were more likely to elicit responses which ‘talked round the action’ in a sentence production context than those in the high action condition, leading to the effect seen. Such potential effect of constraint was not controlled for in this study but may wish to be examined further and considered in any future studies looking at verb production at a single word and sentence level.

The last analysis conducted in relation to this research question was concerned with the influence of the complexity of a verb’s argument structure on production. Findings would suggest that sentences within which movement of a sentence element from its base position was required (i.e., the unaccusative reading) were produced less accurately than those which did not. Again, no main or interacting effect of group was seen, suggesting that the pattern of performance in the PD group did not differ significantly from that controls. Because previous studies looking at the production of unaccusative sentences in individuals with Broca’s aphasia have used either individuals with Wernicke’s aphasia as the control group (Bastiaanse & van Zonneveld, 2005) or conducted within group comparisons (Thompson, 2003) there is little context within which to consider the pattern seen here in neurotypical control participants. It could simply be the case that an effect of syntactic argument complexity is also seen in neurotypical individuals. An alternative explanation is that the pattern seen is reflective the design of the task. The majority of errors in the unaccusative condition reflected the use of the passive, transitive construction, within which the object (the actor, carrying out the action) can legitimately be dropped. So, in instances within which no actor was present, there was a tendency for the same transitive construction to be adopted, but in the passive form (for example, rather than saying the target sentence of ‘the chocolate is melting’, the response might be ‘the chocolate is being melted’).

This pattern could potentially reflect the task materials. Whilst all were carefully designed to be able to elicit unaccusative sentences, it is possible that some of the provided verbs were used more commonly in the unaccusative reading than others in everyday parlance, which could have influenced the results seen here. It is therefore suggested that future studies either control for how common each construction is within everyday language use or consider adopting a different approach (the comparison of unaccusative vs intransitive verbs, for example). Given the fact that the actor is technically the recipient of the action within unaccusative constructions (Cousins et al., 2018), comparing the production of verbs in this and intransitive readings may provide useful insights into language processing in PD.

Summary

Overall, verb production accuracy was not found to be differentially influenced by action and/or grammatical complexity in PD, as compared with controls, at either a single word or sentence level. Whilst both action and transitivity were found to have a significant influence on verb production, this influence did not vary between the PD and control group. This finding was not as predicted, and stands in contrast to previous findings (e.g., Bocanegra et al., 2017). Potential reasons for this finding – both in relation to potential confounds within the verb stimuli and the characteristics of the PD group in this study – have been discussed, with particular focus on the potential confound of semantic association. When considering RT, a slight difference in the pattern of influence of the verb’s semantic and grammatical characteristics between groups was seen, potentially reflecting a speed/accuracy trade-off in the PD group.

Again, against predictions, there was no difference in the pattern of influence of grammatical complexity, as measured through the complexity of the verb’s argument structure, on production accuracy. There is little context within which to consider the significant influence of verb reading within both the control and PD group and this could be an avenue for future research. The possibility that the pattern seen may have reflected the design of the task was also considered.

5 The influence of a verb's grammatical complexity and/or associated action, and conceptual level processing, on sentence construction in Parkinson's Disease

5.1 Introduction

Presented within this chapter is the investigation designed to explore the influence of a verb's characteristics – namely the action associated with its meaning, and the number of syntactic arguments taken – on sentence construction. Of separate interest too, was the influence of the number of conceptual options elicited by two provided words on the same measures of sentence construction. Sentence construction was considered according to three measures: fluency, lexical content and the time taken to formulate a response, as measured through response time (RT). A reminder of the Research Question and component sub-questions, within the context of the whole study, is provided in Figure 21.

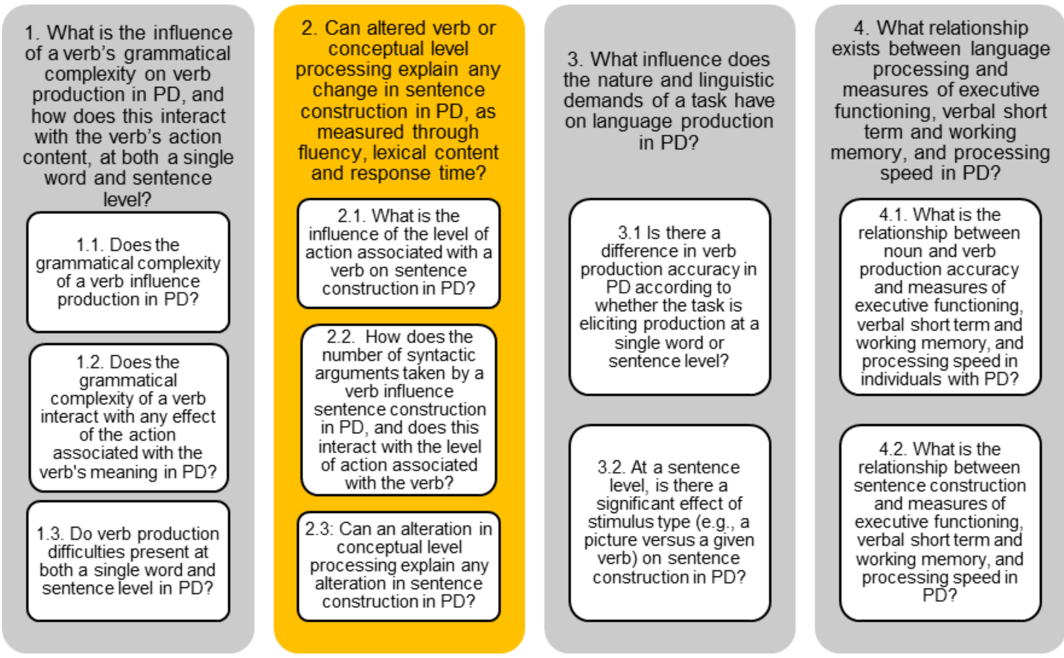


Figure 21. Research questions and sub-questions: focus on Research Question 2

It was anticipated that verbs which proved more difficult for individuals with PD to process would negatively impact upon sentence construction. As such – in line with the hypothesis made in relation to verb retrieval (see Section 4.1) – it was predicted that high action verbs, and/or verbs taking a greater number of syntactic arguments, would lead to the production of sentences which were shorter, of lower lexical density and less fluent than those produced using low action verbs requiring fewer syntactic arguments. It was anticipated, too, that this same effect would be seen on RT. No such effect was anticipated in the control group.

Given findings to suggest that mechanisms of selection and the inhibition of competing alternatives may be impacted upon in PD (e.g., Crescentini, Mondolo, et al., 2008), it was hypothesised that individuals would find it more difficult to produce a sentence in response to word-pairs which elicit a high number of conceptual options than to those which elicit fewer conceptual options. Thus, it was hypothesised that sentences produced in the context of multiple conceptual options would be less fluent, shorter and of lower lexical density. No effect of the number of conceptual options was expected in the control group. A reminder of the hypothesis relating to each sub-question is provided below:

RQ 2.1. What is the influence of the level of action associated with a verb on sentence construction in PD?

> *Hypothesis: Sentences produced by individuals with PD in response to pictures depicting high action verbs will be shorter, of lower lexical density, less fluent, and take longer to formulate. No effect will be evident in the control group.*

RQ 2.2. How does the number of syntactic arguments taken by a verb influence sentence construction in PD, and does this interact with the level of action associated with the verb?

> *Hypothesis: An interaction between the number of syntactic arguments that can be taken by the verb and action will be observed in PD, such that sentences produced using grammatically complex, high action verbs will be shorter, of lower lexical density, less fluent, and take longer to formulate. No effect will be evident in the control group.*

RQ 2.3 Can an alteration in conceptual level processing explain any alteration in sentence construction in PD?

> *Hypothesis: Alterations in conceptual level processing will present in PD, leaving sentences produced in response to words providing more conceptual options being shorter, of lower lexical density and less fluent. No such effect will be evident in the control group.*

Data from three tasks formed the basis of the analysis (see Section 5.2):

1. A sentence production task eliciting the production of sentences from picture stimuli. Of interest was the influence of the depicted verb's degree of associated action on sentence construction.
2. A one word sentence generation task eliciting the production of sentences from a given verb. Of interest was the influence of both the level of associated action and the number of syntactic arguments taken by the verb on sentence production.
3. A two word sentence generation task eliciting the production of sentences from a given word-pair. Of interest was whether the degree of relatedness

between the word-pairs, which in turn influenced the number of conceptual options made available, influenced sentence construction.

Detailed information regarding the materials utilised within these tasks and the procedures adhered to are outlined in the section which immediately follows (Section 5.2). This leads into an overview of the results, presented in terms of each research question, with a summary provided at the close of each subsection (Section 5.3). Finally, a discussion of the findings relating to the sub-questions and related hypotheses is presented (Section 5.4).

5.2 Methods

A mixed factorial design was adopted to assess the influence of action, action and transitivity, and conceptual level processing ability on sentence construction, with group the between-subjects factor for all analyses.

5.2.1 Sentence Production Task

As outlined in Section 4.2.2, one dual-purpose sentence production task was utilised within the study. Its first purpose was to assess the production of verbs at a sentence level in PD (see 4.3.2 for the results of this analysis). The second purpose, reported upon here, was to assess the influence of the degree of action associated with the verb on measures of sentence construction.

Materials

The same 56 verbs and corresponding picture stimuli utilised within the verb naming were employed within the sentence production task. Full details of the verb list and corresponding stimuli can be found in Sections 4.2.2 and 4.2.3.

In this analysis, of sole interest was the influence of the action associated with a verb on sentence construction. Verbs in the low and high action condition were matched for all word characteristics (Frequency: $U = 395$, $p = .967$; AoA: $U = 356$, $p = .555$; Concreteness: $U = 439$, $p = .441$; Length: $U = 392$, $p = 1.00$; Orthographic Neighbours: $U = 425$, $p = .590$; Phonological Neighbours: $U = 362$, $p = .615$).

Procedure and Scoring

For full detail regarding how the task was run, see Section 4.2.2. To summarise, participants were shown a picture in the centre of laptop screen, with a sentence starter (e.g., ‘the man is…’ provided underneath. They were asked to produce a sentence describing the action depicted in the picture, using the sentence starter provided. The sentences produced were analysed according to the linguistic measures outlined below.

Fluency

Two sub-measures of fluency were calculated: a dysfluency percentage score and a measure of average pause length. An overall, dysfluency percentage was favoured to constrain the number of analyses being conducted. Dysfluencies were defined as medial and between clause pauses (including filled pauses), false starts/restarts, verbal fillers (*only* those which appeared within the sentence), word repetitions and sound repetitions. Word repetition was defined as any immediate repetition of a word or short phrase. If there was a gap of 200ms or more between the words, this was considered a re-start. Sound repetitions were counted in units, i.e., in the sentence ‘*th- th- the woman is d- d- dancing’*, two examples of sound repetition would be logged. The number of each type of dysfluency per sentence was logged. If no examples were evident, a score of zero was given. A raw score, per participant, was calculated by summing the number of dysfluencies per sentence. Each participant's dysfluency percentage score was then calculated by dividing the total number of dysfluencies by the total word count per condition and multiplying each figure by 100.

Pause lengths were calculated as outlined in Section 2.3.3. Pause lengths occurring within clauses and between clause boundaries were separately logged. However, due to the limited number of pauses which occurred at clauses boundaries, within and between clause pauses were combined for the purposes of analysis.

Lexical Content

Lexical content encompassed three sub-measures: utterance length, lexical density and word errors. Utterance length constituted the overall word count of the sentence taken as the individuals answer (see Section 4.2.2 for further detail regarding this procedure), minus any interjections (e.g., *'I think'*), errors (i.e., false starts) and optional predicates (e.g., the man is eating *or drinking* in the chair), which were not counted. Each participant's mean utterance length, per condition, was calculated by dividing the summed utterance lengths by the number of utterances; as per the protocol followed when calculating mean RT. Lexical density consisted of the percentage of content words, per utterance. This score was calculated as follows. First, the number of content words per sentence was marked, with one point given to every content word within an utterance. Summation of the number of content words, per condition, formed individuals' raw scores. The lexical density score was calculated by dividing this raw score by the total word count per condition and multiplying that figure by 100. Word errors represented any examples whereby an individual had used an incorrect word. Non-target but acceptable verbs were not counted as word errors; the category was limited to incorrect word use. A 'point' was given for each word error evident, and 0 awarded if no errors presented. The number of word errors evident were then summed, before being divided by the total word count and multiplied by 100 to create a percentage word error score per condition, per participant.

Response Time

RT was calculated using the protocol outlined in Section 3.2.3, with the following exception and additions. Responses either <250ms or >15000ms were excluded (representing three responses, or 0.25% of all correct responses). If any participant read aloud the sentence starter provided on the screen and then immediately paused for 200ms or more, this (i.e., the pause and sentence starter) was included in the RT.

5.2.2 One Word Sentence Generation Task

The one word sentence generation task was designed to assess the influence of both a verb's action and the number of syntactic arguments taken by the verb (transitivity) on sentence construction. In contrast to the language tasks described up to this point, this task did not use picture stimuli. Instead, individuals were provided with a written verb and asked to use that verb to create a sentence.

Materials

The same list of 56 verbs detailed in Section 4.2.1 were utilised within this task. Stimuli constituted a written verb, written in all lower case, shown via the laptop.

Procedure and Scoring

Participants were shown each verb in turn and asked to make a sentence using that word. Participants were asked to say the sentence aloud as soon as they could. An illustration of the procedure is provided in Figure 22. Stimuli were delivered across two equal blocks. Linguistic analysis was conducted, and RT calculated as outlined in the previous section (5.2.1). Eight responses > 15000ms (representing 0.47% of correct responses) were removed.

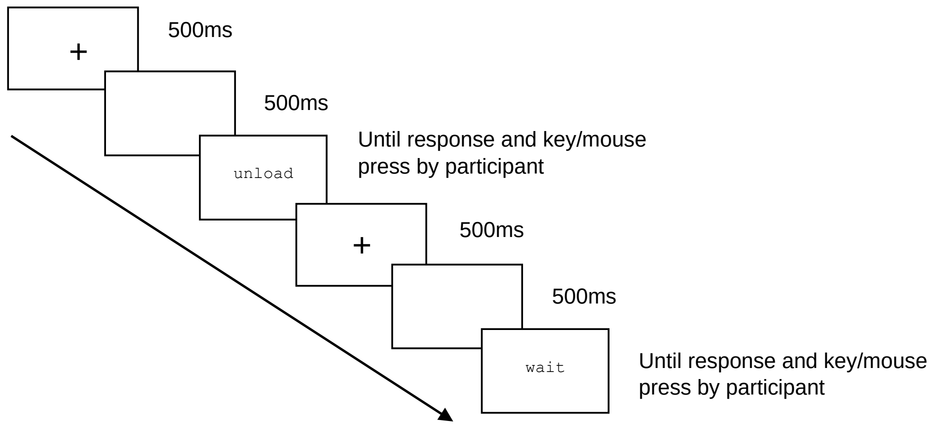


Figure 22. Procedure for One Word Sentence Generation Task

5.2.3 Two Word Sentence Generation Task

Whether alterations in conceptual level processing were contributing to any alteration in sentence production in PD was investigated through a two word sentence generation task. Specifically of interest was the influence of the number of conceptual options elicited by a provided word-pair on sentence construction. This number of conceptual options was manipulated through controlling how related the two words provided were; a method often seen utilised within the literature examining dynamic aphasia (e.g., Robinson et al., 1998).

Materials

The stimuli consisted of word-pairs, comprising one verb and one noun, which varied in their relatedness – and, by extension, the number of conceptual options available. A list of 10 word-pairs were created, with five pairs being highly related (e.g., ‘sing’ and ‘audition’) and five pairs being loosely related (e.g., ‘revise’ and ‘sunshine’). The full word list can be found in Appendix Q. All words (both the nouns and verbs, across categories) were matched for frequency, $F(3, 16) = 2.23$, $p = .125$, age of acquisition (AoA), $\chi^2(3) = 0.097$, $p = .992$, concreteness, $F(3, 16) = 2.54$, $p = .093$, length, $F(3, 16) = 1.50$, $p = .252$, phonological neighbours, $\chi^2(3) = 1.34$, $p = .720$, and orthographic neighbours, $\chi^2(3) = 4.03$, $p = .259$. The written stimuli were presented via a laptop.

Procedure and Scoring

The task proceeded according to the paradigm outlined in Figure 22. An example stimulus is presented in Figure 23.

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propose   restaurant

Figure 23. Example stimulus utilised in the two word sentence generation task

Each word-pair was presented in turn, and participants asked to create a sentence using those words. Whilst the words were presented such that the verb was always shown on the left of the screen and the noun always shown on the right, it was stressed that participants could use the words in either order within their sentence. Participants were asked to say the sentence aloud as soon as they could, once it had been thought of.

Sentences were analysed in terms of their fluency and lexical content according to the protocol outlined in Section 5.2.1. RT was calculated as outlined in the same section. A total of two responses (translating to 0.69% of all correct responses) were removed due to exceeding the upper limit of 15000ms.

5.3 Results

5.3.1 The influence of verb and conceptual processing on sentence fluency

In all three of the tasks employed, fluency was assessed using two sub-measures: the percentage of dysfluencies per utterance and average pause length. Findings from the sentence production task, within which individuals were asked to produce a sentence in response to a given picture, are presented first. This is followed by results obtained from the one word sentence generation and two word sentence generation tasks, within which individuals were asked to produce a sentence from either a given verb or word-pair respectively.

5.3.1.1 Sentence Production Task: Fluency

To assess the influence of the degree of action associated with a verb’s meaning on each sub-measure of fluency (i.e., the percentage of dysfluencies and average pause length), two 2 (group) x 2 (action) mixed factorial ANOVAs were conducted. To correct for multiple comparisons, Bonferroni adjustment was applied (adjusted α =.025). Only sentences within which the target verb had been used and was acting as a main verb were included within the analysis.

As outlined within the previous chapter, examination of the raw data from the sentence production task highlighted the presence of a greater variability of responses to some stimuli than to others. The data was consequently adjusted to remove the potential confound of stimulus-led variability, through eliminating any stimuli for which the modal response from control participants was not the target (for full detail of this procedure, see Section 3.3.3). This led to the removal of the following 11 verbs from the dataset: one from the low action intransitive condition (‘scowl’), four from the high action, intransitive condition (‘stumble’, ‘collide’, ‘tiptoe’, ‘sob’), one from the transitive optional, low action condition (‘donate’), one from the high action, transitive optional condition (‘swallow’), two from the low action, transitive condition (‘recycle’, ‘sprinkle’) and two from the high action, transitive condition (‘extinguish’, ‘unload’), leaving a total of 45 stimuli. The data are provided in Table 20.

Table 20.

Mean (SD) and mean and median fluency scores in the sentence production task, as a function of group and action

		PD	Control
		Mean (SD)	Mean (SD)
		Median (IQR)	*Median (IQR)*
Dysfluencies (% Score)	Low	10.0 (4.89)	8.26 (7.41)
		9.50 (6.47)	*6.15 (8.70)*
	High	10.9 (7.21)	9.28 (8.82)
		9.42 (9.99)	*6.60 (9.56)*
Pause Length (ms)	Low	858 (323)	586 (240)
		767 (355)	*497 (279)*
	High	687 (273)	537 (151)
		612 (266)	*541 (262)*

Analysis concerned with the percentage of dysfluencies per condition is presented first (adjusted α =.025). No significant main effect of action, $F(1,39) = 1.86$, $MSE = 9.28$, $p = .180$, $\eta_p^2 = .046$, or group, $F(1, 39) = 0.54$, $MSE = 102$, $p = .465$, $\eta_p^2 = .014$ was evident, and there was no interaction between the variables, $F(1,39) = 0.013$, $MSE = 9.28$, $p = .908$, $\eta_p^2 = .000$. Note, data for this ANOVA contained significant outliers and failed the assumption of normality.

Analysis concerned with pause length (adjusted α =.025) indicated a significant main effect of group, $F(1,39) = 12.4$, $MSE = 69614$, $p = .001$, $\eta_p^2 = .24$, with, collapsed across action condition, average pause length shown to be greater in the PD (*estimated marginal mean [EMM]* = 772ms, *SE* = 46.6ms) as compared with the control group (*EMM* = 562ms, *SE* = 37.3ms). No other main effects or interactions were significant (all $p > .034$). Because data for neither the ANOVA nor between-subjects comparison met all necessary assumptions for parametric analysis, a

Mann-Whitney U test was additionally conducted (adjusted α =.025). The results supported a significant main effect of group, U = 77.0, p = .001, r = 0.51.

Summary of Results

Two aspects of fluency were of interest: the percentage of dysfluencies present (as measured through the collective percentage of pauses, false starts/restarts, verbal fillers which appeared within the sentence, word repetitions and sound repetitions) and average pause length.

Analysis showed there to be no significant effect of either action or group on the percentage of dysfluencies evident, or significant interaction between these two variables. In contrast, group was found to have a significant effect on pause length with, collapsed across action conditions, pauses found to be significantly longer in the PD group.

5.3.1.2 One Word Sentence Generation Task: Fluency

Again, to assess the effect of the independent variables of interest on each of the fluency sub-measures, two mixed factorial ANOVAs were conducted (adjusted α = .025). Any sentence within which the target verb had been used as a noun, or was not acting as the main verb, was excluded from the analysis. One participant was excluded from the analysis entirely, due to having misunderstood the task (n = 40).

To first investigate the effect of group, action and transitivity on the percentage of dysfluencies per utterance, a 2 (group) x 2 (action) x 4 (transitivity) mixed factorial ANOVA was conducted. Three individuals with PD had missing data points and were consequently excluded from the ANOVA (n = 37).

The second analysis was concerned with average pause length. Due to the number of missing data points evident within the dataset for this measure, the data was collapsed across transitivity and a 2 (group) x 2 (action) mixed factorial ANOVA consequently conducted. Two participants (one PD and two controls) had no example pauses within a condition and were thus excluded from the ANOVA (n = 37). The data for both analyses are presented in Table 21.

Table 21.

Mean (SD) and median (IQR) fluency scores in the one word sentence generation task, as a function of group, action and the number of syntactic arguments taken by the verb (transitivity)

		PD		Control	
		Low	High	Low	High
		Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
Dysfluencies	Intransitive	6.05 (5.29)	9.08 (6.23)	5.64 (4.80)	7.09 (8.37)
(% Score)		*3.23 (9.00)*	*7.55 (8.86)*	*5.81 (8.61)*	*5.13 (8.15)*
	Transitive Optional	6.69 (5.28)	10.5 (11.3)	6.15 (6.64)	6.77 (6.92)
		5.88 (8.25)	*9.38 (13.3)*	*4.58 (6.54)*	*5.01 (13.8)*
	Transitive	8.56 (6.62)	5.73 (5.58)	7.83 (8.04)	7.53 (8.71)
		7.69 (7.16)	*4.76 (6.28)*	*5.40 (11.2)*	*5.97 (6.40)*
	Ditransitive Optional	3.52 (3.81)	10.4 (11.5)	6.64 (6.11)	6.42 (5.98)
		2.86 (6.85)	*7.69 (11.3)*	*4.82 (8.36)*	*5.47 (11.9)*
Pause Length		639 (239)	610 (196)	645 (239)	566 (208)
(ms)		*605 (234)*	*603 (288)*	*596 (319)*	*520 (238)*

The ANOVA concerned with the percentage of dysfluencies per sentence was first conducted (adjusted α =.025). No significant main effect of action, $F(1, 35) = 4.48$, $MSE = 36.6$, $p = .041$, $\eta_p^2 = .11$, transitivity, $F(3, 105) = 0.34$, $MSE = 26.1$, $p = .794$, $\eta_p^2 = .010$, or group, $F(1, 35) = 0.23$, $MSE = 194$, $p = .637$, $\eta_p^2 = .006$ presented. All interactions were non-significant (all $p > .09$). Note, data for the ANOVA contained significant outliers and failed the assumption of normality.

The analysis concerned with pause length (adjusted α =.025), indicated no significant main effect of action, $F(1, 35) = 1.10$, $MSE = 48674$, $p = .302$, $\eta_p^2 = .030$, or group, $F(1, 35) = 0.13$, $MSE = 49814$, $p = .719$, $\eta_p^2 = .004$, or significant interaction between the variables, $F(1, 35) = 0.23$, $MSE = 48674$, $p = .634$, $\eta_p^2 = .007$. Note, data for the ANOVA failed the assumption of normality.

Summary of Results

Results indicated no significant main effect of group, action or transitivity on the percentage of dysfluencies within a sentence constructed using a given verb. Further, no interactions between any of these three variables of interest were evident. These findings were mirrored in the analysis concerned with average pause length. This measure was not found to be influenced significantly by either group or the degree of action associated with the verb; nor did an interaction between these variables present.

5.3.1.3 Two Word Sentence Generation Task: Fluency

Two analyses were conducted to assess the effect of the independent variables of interest on each of the two fluency sub-measures (adjusted α =.025). In this instance, the two independent variables were group and the number of conceptual options elicited by the provided word-pair, as manipulated through the relatedness of the two component words. Only sentences within which the target verb and noun had been used correctly were included in the analysis. The same control participant excluded from analyses conducted on data from the one word sentence generation task was again excluded here, due to having misunderstood the task ($n = 40$).

To assess the effect of group and word-pair relatedness on the percentage of dysfluencies, a 2 (group) x 2 (word-pair relatedness) mixed factorial ANOVA was conducted. The same test was planned to evaluate pause length however, due to the limited number of pauses made, the decision was taken instead to assess pause length according to one variable only: group. Due to having no example pauses, one PD and four further control participants were necessarily excluded from the analysis exploring pause length (*n* = 35). The data are presented in Table 22.

Table 22.

Mean (SD) and median (IQR) fluency scores in the two word sentence generation task, as a function of group and word-pair relatedness

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Dysfluencies (% Score)	Highly Related	9.68 (10.1)	6.13 (6.31)
		7.29 (19.4)	*5.32 (8.24)*
	Loosely Related	14.4 (12.6)	8.42 (6.68)
		9.88 (19.5)	*7.23 (6.12)*
Pause Length (ms)		647 (266)	636 (307)
		573 (250)	*550 (396)*

The ANOVA (adjusted α =.025) concerned with the percentage of dysfluencies per sentence evidenced no significant main effect of group, $F(1, 38) = 4.08$, $MSE = 107$, $p = .050$, $\eta_p^2 = .097$ or word-pair relatedness, $F(1, 38) = 5.15$, $MSE = 46.0$, $p = .029$, $\eta_p^2 = .12$. Further, no significant interaction between these variables was present, $F(1, 38) = 0.63$, $MSE = 46.0$, $p = .434$, $\eta_p^2 = .016$. Note, data for the ANOVA violated all assumptions.

A Mann-Whitney U test (adjusted α =.025) was employed to assess the effect of group on average pause length. No significant main effect of group was indicated, $U = 142$, $p = .780$, $r = 0.048$.

In sum, the number of conceptual options elicited by a provided word-pair – as measured through relatedness of those two words – was not found to influence the fluency of sentences in either the PD or control group. There was neither any evidence of a significant effect of group on the percentage of dysfluencies evident, collapsed across word-pair relatedness. This latter finding was mirrored in the analyses concerned with average pause length, with no significant difference in mean pause length between groups evident.

5.3.1.4 Overall Summary of Results (Fluency)

Collectively, analyses conducted across the three tasks showed neither action, transitivity, the number of conceptual options (as measured through word-pair relatedness) nor group to have a significant main effect on the percentage of dysfluencies evident within a given sentence. Notably, group was not found to interact significantly with any of the within-subjects factor(s), indicating patterns of dysfluency to be similar between groups. Collapsed across group, no significant interaction between the associated action and transitivity of the verb was evident.

In contrast, pause length was found to be significantly influenced by group with, on average, longer pauses found to be evident in sentences produced by individuals with PD. This effect however was only seen in sentences produced in response to picture stimuli (sentence production task); in neither of the tasks within which written words were provided was a significant main effect of group shown. Across tasks, neither action nor transitivity was shown to influence pause length and no significant interaction between these variables and/or group was evident.

5.3.2 The influence of verb and conceptual processing on the lexical content of a sentence

From each of the three tasks, three sub-measures of lexical content were analysed: utterance length, lexical density (as measured through the percentage of content words per utterance) and word errors (as a percentage of total word count). Bonferroni adjustment for multiple comparisons was consequently applied, setting the required alpha to .017. Results relating to utterance length and lexical density, from each of the three sentence construction tasks, are presented in the same order as followed in the previous section. Results pertaining to word errors from across all three tasks are presented collectively in Section 5.3.2.4.

5.3.2.1 Sentence Production Task: Lexical Content

To assess the influence of group and action on utterance length and lexical density, two 2 (group) x 2 (action) mixed factorial ANOVAs were conducted. Only sentences within which the target verb had been used and was acting as a main verb were included within the analysis. One participant, whose data presented as a significant outlier, was excluded from the lexical content analysis due to consistent omission of the initial determiner; despite it having been provided in the sentence starter. Thus, for all analyses relating to lexical density, $n = 40$.

The dataset adjusted as outlined within the previous section (Section 5.3.1.1) was utilised for the analysis. The data are outlined in Table 23.

Table 23.

Mean (SD) and median lexical content scores in the sentence production task, as a function of group and action

	PD		Control	
	Low	High	Low	High
	Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
Utterance Length	7.91 (1.79)	7.25 (1.65)	7.87 (2.89)	7.77 (3.40)
	7.68 (1.59)	*6.82 (1.95)*	*6.53 (4.21)*	*6.76 (3.72)*
Lexical Density	47.6 (2.50)	48.8 (2.17)	48.3 (1.96)	48.4 (2.72)
(% Content Words)	*46.9 (1.90)*	*48.3 (3.42)*	*48.8 (3.31)*	*48.8 (3.53)*

The ANOVA concerned with utterance length (adjusted α = .017) was first conducted. Analysis revealed a significant main effect of action, *F*(1, 39) = 11.0, *MSE* = 0.26, *p* = .002, η_p^2 = .22, with, collapsed across groups, more said in response to low (*EMM* = 7.89, *SE* = 0.40) as compared with high action stimuli (*EMM* = 7.51, *SE* = 0.46). No other comparisons were significant (all *p* ≥ .018). Because data for neither the ANOVA nor within-subjects comparison met all assumptions for parametric analysis, a non-parametric Sign test was run (adjusted α = .017). This did not however corroborate the previously reported main effect of action, *z* = -2.37, *p* = .018, *r* = 0.37.

Lexical density was next considered. This analysis (adjusted α = .017) indicated neither action, *F*(1, 38) = 3.32, *MSE* = 2.47, *p* = .076, η_p^2 = .080, nor group, *F*(1, 38) = 0.33, *MSE* = 8.70, *p* = .856, η_p^2 = .001, to have a significant main effect on lexical density. Further, no significant interaction between the variables was evident, *F*(1, 38) = 2.01, *MSE* = 2.47, *p* = .164, η_p^2 = .050. Note, data for the ANOVA did not meet all necessary assumptions.

Summary of Results

Collapsed across group, action was indicated to have a significant main effect on utterance length, with more said in the low action condition. This finding was not however corroborated by non-parametric analysis. No significant main effect of group on utterance length presented, nor did a significant interaction between group and action exist. A similar pattern was seen when considering lexical density. Here, neither action nor group were found to significantly influence a sentence's lexical density, nor was a significant interaction between these variables seen.

5.3.2.2 One Word Sentence Generation Task: Lexical Content

Two, 2 (group) x 2 (action) x 4 (transitivity) ANOVAs were conducted to investigate the influence of group, action and the number of syntactic arguments taken by the verb (transitivity) on the length and lexical density of sentences produced in response to a given verb. Only sentences within which the target had been used as a main verb were included in the analysis. Data are presented in Table 24 below. Due to missing data points, three individuals were excluded from both ANOVAs, in addition to the control participant excluded from all analyses involving this task (PD: n = 13; Controls: n = 24; Group Sample Size: n = 37).

Table 24.

Mean (SD) and median (IQR) lexical content scores in the one word sentence generation task, as a function of group, action and the number of syntactic arguments taken by the verb (transitivity)

		PD		Control	
		Low	High	Low	High
		Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
Utterance Length	Intransitive	6.30 (1.74)	6.59 (1.91)	5.90 (1.29)	6.58 (1.34)
		6.14 (1.67)	*6.29 (2.72)*	*5.66 (1.49)*	*6.40 (1.79)*
	Transitive Optional	6.32 (2.43)	6.31 (1.11)	6.02 (1.11)	5.80 (1.30)
		5.85 (1.45)	*6.14 (1.87)*	*5.71 (1.52)*	*5.60 (2.07)*
	Transitive	6.27 (1.75)	6.19 (1.35)	6.47 (1.58)	6.13 (1.18)
		5.60 (2.72)	*5.67 (1.09)*	*6.17 (1.81)*	*5.90 (1.60)*
	Ditransitive Optional	6.21 (1.36)	6.11 (1.26)	6.17 (1.72)	6.19 (1.67)
		5.86 (1.74)	*6.00 (1.85)*	*6.00 (1.97)*	*5.84 (1.81)*
Lexical Density (% content words)	Intransitive	47.0 (7.02)	46.9 (5.32)	51.3 (8.13)	51.1 (7.62)
		47.1 (10.1)	*46.7 (5.80)*	*50.8 (11.5)*	*49.5 (6.36)*
	Transitive Optional	50.5 (8.08)	49.2 (8.18)	51.1 (6.11)	52.6 (10.6)
		50.0 (8.55)	*47.6 (15.4)*	*50.0 (7.78)*	*50.0 (6.77)*
	Transitive	48.1 (3.26)	50.0 (6.78)	52.4 (11.6)	51.7 (7.99)
		46.4 (3.84)	*48.5 (9.96)*	*50.0 (6.22)*	*51.1 (10.6)*
	Ditransitive Optional	48.8 (5.46)	52.2 (5.18)	54.7 (10.0)	53.6 (11.2)
		50.0 (6.21)	*51.4 (4.03)*	*50.9 (8.08)*	*52.3 (7.38)*

From the analysis concerned with utterance length (adjusted $\alpha = .017$), no significant main effect of group, $F(1, 35) = 0.088$, $MSE = 13.3$, $p = .768$, $\eta_p^2 = .003$, action, $F(1, 35) = 0.10$, $MSE = 0.63$, $p = .754$, $\eta_p^2 = .003$ or transitivity, $F(3, 105) = 0.93$, $MSE = 0.75$, $p = .428$, $\eta_p^2 = .026$ was evident. All interactions were non-significant (all $p > .067$). Note, data for the ANOVA did not meet all necessary assumptions.

For lexical density, analysis (adjusted $\alpha = .017$) revealed a significant main effect of transitivity, $F(3, 105) = 3.88$, $MSE = 30.9$, $p = .011$, $\eta_p^2 = .10$. No other main effects or interactions were significant (all $p > .18$). Post-hoc analysis ($\alpha = .05$)[10] indicated lexical density in the intransitive condition ($EMM = 49.1$, $SE = 1.10$) to be significantly lower than that in the ditransitive optional condition ($EMM = 52.3$, $SE = 1.49$; $p = .041$). Descriptive analysis did not indicate this difference to reflect any difference in the percentage of word omissions per condition ($M_{Int} = 1.20$, $SD_{Int} = 3.86$; $M_{Ditrans} = 1.11$, $SD_{Ditrans} = 4.94$). All other comparisons were non-significant (all $p > .28$).

Because neither the ANOVA nor the within-subjects comparison met all the assumptions for parametric testing, a Friedman's test was additionally run (adjusted $\alpha = .017$). Findings from this analysis did not enforce presence of a significant main effect of transitivity, $\chi^2(3) = 8.43$, $p = .038$.

Summary of Results

Neither action, transitivity, nor group was found to have a significant effect on the length of utterances produced within the one word sentence generation task. In slight contrast, collapsed across both action and group, a significant main effect of transitivity on lexical density was indicated. This finding was not however corroborated by non-parametric analysis.

5.3.2.3 Two Word Sentence Generation Task: Lexical Content

To assess the effect of group and the number of conceptual options elicited by a given word-pair (as measured through the relatedness of those words) on utterance length and lexical density respectively, two, 2 (group) x 2 (word-pair relatedness) mixed factorial ANOVAs were run. Only sentences within which the target verb and noun had been used correctly were included in the analysis. The data are presented in Table 25 (*n* = 40, reflecting the exclusion of one control participant who misunderstood the task).

Table 25.

Mean (SD) and median (IQR) utterance length and lexical density scores, according to group and word-pair relatedness

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Utterance Length	Highly Related	9.60 (2.32)	9.17 (2.05)
		9.25 (2.30)	*8.90 (2.38)*
	Loosely Related	9.95 (3.07)	9.45 (1.88)
		8.75 (4.76)	*9.30 (2.11)*
Lexical Density	Highly Related	42.8 (6.27)	43.4 (5.63)
(% content words)		*41.4 (12.0)*	*43.8 (9.49)*
	Loosely Related	44.7 (3.94)	44.6 (4.34)
		44.7 (6.24)	*44.2 (7.20)*

Analysis (adjusted α =.017) revealed no significant main effect of word-pair relatedness, $F(1, 38) = 0.84$, $MSE = 2.34$, $p = .367$, $\eta_p^2 = .022$, or group, $F(1, 38) = 0.52$, $MSE = 8.19$, $p = .476$, $\eta_p^2 = .013$, on utterance length, nor was a significant interaction evident, $F(1, 38) = 0.012$, $MSE = 2.34$, $p = .915$, $\eta_p^2 = .000$. Note, data for the ANOVA contained significant outliers and violated the assumption of normality and homogeneity.

A similar pattern was evident in the analysis (adjusted α =.017) considering lexical density, with no significant main effect of word relatedness, $F(1,38) = 2.38$, MSE =

19.8, p = .131, η_p^2 = .059, group, F(1, 38) = 0.052, MSE = 32.4, p = .821, η_p^2 = .001, or interaction, F(1,38) = 0.13, MSE = 19.8, p = .725, η_p^2 = .003.

In sum, neither group nor the word-relatedness of a given word-pair was shown to have any significant effect on the length of a produced utterance, or the lexical density of that utterance. The same pattern presented in both individuals with PD and controls.

5.3.2.4 Word Errors

Overall, few word errors were evident in any of the sentence construction tasks. As such, only the effect of group on percentage word errors was assessed. Mann-Whitney U tests were utilised to compare performance between groups within each task. Only sentences within which the target verb had been used and was acting as a main verb were included within the analysis. For the sentence production task, the adjusted data set was utilised. All data are provided in Table 26.

Table 26.

Mean (SD) and mean ranked word error scores, according to group

	PD	Control
	Mean (SD)	Mean (SD)
	Mean ranked score	*Mean ranked score*
Sentence Production	0.087 (0.21)	0.040 (0.14)
(% Errors)	*22.3*	*20.2*
One Word Sentence Generation	0.024 (0.095)	0.042 (0.14)
(% Errors)	*20.2*	*20.7*
Two Word Sentence Generation	0.12 (0.48)	0.17 (0.48)
(% Errors)	*19.8*	*20.9*

Analysis (adjusted α =.017) revealed no difference in the percentage of word errors evident between groups in the sentence production, $U = 180$, $p = .335$, $r = 0.15$, one word sentence generation, $U = 197$, $p = .762$, $r = 0.048$ or two word sentence generation, $U = 203$, $p = .578$, $r = 0.088$, tasks. In total, five participants made errors in the sentence production task (three PD and two controls), three in the sentence generation task (one PD and two controls) and four in the two word sentence generation task (one PD and three controls).

To assess whether any difference in the likelihood of individuals making a word error – across tasks – existed, according to whether they were in the PD or control group, a Fischer's Exact test was conducted. A binary measure of word errors was created, separating individuals who had made any word errors (regardless of number) across the tasks, and those who had not. The Fischer's Exact test indicated no significant association between group and the production of word errors ($p = .723$), with six controls (24.0%) making at least one word error across tasks, and five individuals with PD (31.3%).

Summary of Results

Few participants made word errors, and where they did, these errors were limited in number. There were no differences in the number of word errors per group, across any of the sentence construction tasks. Individuals with PD were no more likely to make a word error than control participants.

5.3.2.5 Overall Summary of Results (Lexical Content)

Neither transitivity, group, nor the number of conceptual options elicited by a given word-pair were found to have a significant main effect on utterance length. Further, no significant interaction between group and verb transitivity, action, nor the number of conceptual options elicited was evidenced. There was indication of a significant main effect of action on the length of utterances produced in response to picture stimuli, however this was not supported by non-parametric analysis.

When considering the lexical density of sentences, a significant main effect of transitivity on sentences produced in the one word sentence generation task was indicated, however once again this finding was not corroborated by non-parametric analysis. Neither action, group, nor the number of conceptual options elicited by a word-pair was found to influence the lexical density of produced utterances, nor did any interaction exist between these variables. Finally, word errors were found to be few, and not shown to differ between individuals with PD and controls.

5.3.3 The influence of verb and conceptual processing on response time

As with all previous analyses concerned with RT, only sentences within which the target verb had been used as the main verb (i.e., were 'correct') were included within the analysis. Results from the sentence production task are presented first, followed by those from the one and two word sentence generation tasks, respectively.

5.3.3.1 Sentence Production Task: Response Time

The influence of group and action on RT was assessed using a 2 (group) x 2 (action) mixed factorial ANOVA. Analysis was conducted using the adjusted dataset (for detail, see Section 5.3.1.1). The data are presented in Table 27.

Table 27.

Mean (SD) and median (IQR) RT (ms) scores in the sentence production task, as a function of group and action

		PD	Control
		Mean (SD)	Mean (SD)
		Median (IQR)	*Median (IQR)*
RT (ms)	Low	2207 (752)	2148 (1328)
		1997 (949)	*1837 (931)*
	High	2251 (694)	2194 (1206)
		2114 (1324)	*1778 (1022)*

No significant main effect of action, $F(1,39) = 0.47$, $MSE = 84179$, $p = .497$, $\eta_p^2 = .012$ or group, $F(1,39) = 0.029$, $MSE = 2298939$, $p = .867$, $\eta_p^2 = .001$, on sentence formulation time was evident. There was no interaction between variables, $F(1,39) = 0.00$, $MSE = 84179$, $p = .983$, $\eta_p^2 = .000$. Note, data for the ANOVA contained outliers and violated the assumption of normality.

5.3.3.2 One Word Sentence Generation Task: Response Time

A 2 (group) x 2 (action) x 4 (transitivity) mixed factorial ANOVA was conducted to assess the effect of group, action and the number of syntactic arguments taken by the verb (transitivity) on the time taken to produce a sentence in response to a given verb. The data are presented in Table 28. In addition to the control participant excluded from all sentence generation analyses, three further participants were necessarily excluded from the ANOVA, due to having missing data points (PD: $n = 13$; Control: $n = 24$).

Table 28.

Mean (SD) and Median (IQR) RT (ms) scores in the one word sentence generation task, as a function of group, action and the number of syntactic arguments taken by the verb (transitivity)

		PD		Control	
		Low	High	Low	High
		Mean (SD) *Median (IQR)*		Mean (SD) *Median (IQR)*	
RT	Intransitive	2228 (996)	2389 (1122)	2187 (795)	2180 (812)
(ms)		*2051 (1237)*	*2179 (1119)*	*2273 (890)*	*1975 (1162)*
	Transitive Optional	2195 (878)	2332 (1181)	2139 (824)	2546 (1068)
		1996 (1309)	*2104 (590)*	*1915 (971)*	*2357 (1198)*
	Transitive	2389 (1379)	2265 (910)	2291 (969)	2330 (873)
		1989 (1300)	*2296 (810)*	*2139 (829)*	2200 (1102)
	Ditransitive Optional	2420 (1404)	2442 (1334)	2427 (1478)	2401 (1036)
		1957 (1521)	*2068 (1438)*	*1950 (845)*	*2185 (1314)*

No significant main effects were found (all p > .41). No significant interaction between action and group, $F(1, 35) = 0.88$, $MSE = 568852$, $p = .768$, $\eta_p^2 = .003$, transitivity and group, $F(2.37, 85.6) = 0.33$, $MSE = 455462$, $p = .758$, $\eta_p^2 = .009$ action and transitivity, $F(2.45, 85.6) = 0.83$, $MSE = 484709$, $p = .459$, $\eta_p^2 = .023$, or action, transitivity and group, $F(2.45, 85.6) = 0.42$, $MSE = 484709$, $p = .698$, $\eta_p^2 = .012$, was evident. Note, data for the ANOVA failed the assumption of normality and homogeneity of covariances.

5.3.3.3 Two Word Sentence Generation Task: Response Time

A 2 (group) x 2 (word-pair relatedness) ANOVA was conducted to assess the effect of group and word-pair relatedness on the time taken to produce a sentence in response to a given word-pair. The data are presented in Table 29 (*n* = 40, due to the excluded control participant).

Table 29.

Mean (SD) and Median (IQR) RT (ms) scores in the two word sentence generation task, according to group and word-pair relatedness

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
RT	Highly Related	3179 (1179)	3337 (1700)
		3002 (1901)	*2900 (1907)*
	Loosely Related	3608 (1415)	3447 (1513)
		3515 (1858)	*3348 (2281)*

A significant main effect of word-pair relatedness was evident, $F(1, 38) = 6.19$, $MSE = 224716$, $p = .017$, $\eta_p^2 = .14$, with highly related stimuli responded to more quickly ($EMM_{HighlyRelated}$ = 3258ms, $SE_{HighlyRelated}$ = 245ms; $EMM_{LooselyRelated}$ = 3527ms, $SE_{LooselyRelated}$ = 283ms). There was no main effect of group, $F(1, 38) = 0.00$, $MSE = 4249552$, $p = .998$, $\eta_p^2 = .000$, or significant interaction between variables, $F(1, 38) = 2.18$, $MSE = 224716$, $p = .148$, $\eta_p^2 = .054$. While data for the ANOVA contained significant outliers and failed the assumption of normality, data for the within groups (word-pair relatedness) comparison met all assumptions for parametric analysis.

In sum, collapsed across participants, sentences were provided significantly faster in response to word-pairs which elicited fewer conceptual options.

5.3.3.4 Overall Summary of Results (Response Time)

Only the number of conceptual options elicited by a given word-pair, collapsed across groups, was found to significantly influence RT. Neither group, action nor transitivity was shown to have a significant effect on the time taken to produce a sentence, nor did an interaction between any of these variables present.

5.4 Discussion

This investigation aimed to examine the influence of three variables on sentence construction. Sentence construction was itself judged across three measures – fluency, lexical content and response (sentence formulation) time – according to which the discussion here has been arranged. Two of the three variables related to the characteristics of the verb around which the sentence was being formed: the degree of action associated with the verb's meaning, and the verb's grammatical complexity, as measured through the number of syntactic arguments that could be taken (transitivity). The third variable was conceptual options, examined through the production of sentences in response to given word-pairs, which varied in their degree of relatedness (and, therefore, the number of conceptual options available).

Information from three different tasks formed the basis of the analysis. Considerable overlap existed between the sentence production and one word sentence generation tasks. The same verb list was utilised within both tasks, and both subsequent data sets were analysed in relation to the influence of the verb's action on sentence construction, and the effect of group. Where the tasks differed was in the nature of the stimuli provided. In the sentence production task, sentences were produced in response to a picture whereas in the one word sentence generation task sentences were produced in response to a given verb. Further, the analysis of sentences produced in response to a given verb (i.e., in the one word, sentence generation task) extended to include the influence of the transitivity of the given verb.

5.4.1 Fluency

Fluency was considered along two sub-measures: the percentage of dysfluencies (as measured through the number of medial and between clause pauses [including filled pauses], false starts/restarts, verbal fillers, word repetitions and sound repetitions) and average pause length. It was predicted that, in the PD group, the level of action associated with the verb around which the sentence had been built would influence production, with high action verbs leading to decreased fluency. It was expected, too, that when transitivity was introduced into the analysis, a significant interaction would be seen, with sentences produced using high action, grammatically complex verbs (as measured through the number of syntactic arguments taken) being less fluent than those produced in response to low action, syntactically simpler verbs. Findings supported neither of these predictions, with no evidence of a significant effect of either action, transitivity, or interaction between the variables, on the percentage of dysfluencies seen. There was, further, no difference in the pattern of performance seen in the PD as compared with the control group.

The finding that, collapsed across all verb conditions, there was no difference in the percentage of dysfluencies evident in sentences produced by individuals with PD, as compared with controls, is in contrast to findings reported by Troche and Altmann (2012), utilising a similar sentence production task. In both this and Troche and Altmann's (2012) study, dysfluencies were collapsed into a single measure, making it unlikely that the difference reflects any difference in the measurement taken. The difference seen may however reflect cognitive differences between the groups. In this study, there was no significant difference in cognitive performance between individuals with PD and controls, either as measured through general cognitive ability (the M-ACE) or when considering individual cognitive abilities. In contrast, scores within the dementia screen utilised in Troche and Altmann's (2012) study – whilst above the cut-off for dementia – were significantly lower in the PD group as compared with controls. Further, performance within the Stroop and digit ordering tasks was found to be significantly different to that of controls. Thus, it seems plausible to consider that the difference in fluency seen reflects differences in cognitive performance between the groups in each study. That being said, as discussed within Section 1.2.4.2, Troche and Altmann's (2012) analysis would indicate that cognitive ability, whilst contributing to the language alteration seen, could not fully account for it.

What separates this and Troche and Altmann's (2012) study is an understanding of verb processing in the group of individuals with PD. No specific verb deficit was indicated in the group of individuals with PD involved in this study (See Section 3.4.1 for discussion) and, whilst an interacting effect of action and transitivity on verb naming accuracy was indicated (See Section 4.4.1) this pattern did not vary according to group. Thus, in effect these findings support the assertion that, when verb retrieval is *not* significantly impaired in PD, the fluency of sentences built around those same verbs remains commensurately unimpaired. Such a conclusion could appear to be in discordance with findings from previous studies indicating there to be no alteration in either syntactic production (Dick et al., 2018) or measures relating to utterance length, informativeness of content or pattern of pause production (Lee et al., 2019) of groups of individuals with PD who *did* show altered verb retrieval, as compared with controls. However, the key difference between both of these studies and the exploration conducted here is the nature of the tasks employed. In both Lee et al.'s (2019) and Dick et al.'s (2018) studies, verb naming was assessed using a ‘generic’ assessment of verb processing, meaning that the verbs assessed at a single word level were not the same as those elicited within the sentence and discourse level production tasks. Thus, the possibility remains that had a more constrained language task been utilised within those two studies and, importantly, that the task had elicited the same verbs as assessed at a single word level, differences in the sentence construction measurements of interest may have appeared.

Thus, the emerging picture from this and previous studies would suggest that, when verb processing and both specific and general cognitive ability is unimpaired in PD, no alteration in the percentage of dysfluencies evident within sentences presents. When, however, an alteration in specific and general cognitive ability does present, altered sentence fluency is evident; however, does not appear entirely attributable to altered cognition (Troche & Altmann, 2012). The unanswered question that remains therefore is whether altered verb processing alone may lead to an alteration in the percentage of dysfluencies per sentence, or whether it is the combination of altered verb processing *and* altered cognitive ability (whether that be impaired executive functioning, and/or general cognitive ability) that is doing so. Including both individuals’ verb processing ability and cognitive ability as the manipulated variables within future studies may prove elucidating in this regard.

In the analysis concerned with the influence of the number of conceptual options elicited on sentence fluency, findings did not suggest that the presence of a greater number of conceptual options had any significant influence on the percentage of dysfluencies evident within the subsequently produced sentence in individuals with PD, as compared with controls. This, again, was contrary to the predictions made, given previous findings to suggest that common across the language alteration in PD may be a reduced ability to select a response from competing alternatives (e.g., Crescentini, Mondolo, et al., 2008; Silveri et al., 2018) and the evidence of altered conceptual level processing in an individual with dynamic aphasia as the result of a basal ganglia lesion (Crescentini, Lunardelli, et al., 2008). This finding is, however, broadly in line with the pattern of dysfluencies discussed in the previous paragraphs. The number of sentence frames that a verb could allowably take (i.e., whether the verb could only occupy one sentence frame, or multiple) was not shown to significantly influence the fluency of sentences in the PD group – suggesting that, in this group of individuals with PD, increased executive control demands did not lead to reduced sentence fluency (as measured through the percentage of dysfluencies evident within the sentence).

It is important to consider the possibility that understanding of the findings here was limited by the inclusion of only one comparator group (i.e., healthy control participants). Including a second clinical group with different neuropathology may have highlighted subtle differences in functioning – as measured through different patterns of performance in response of the demands of the task – that could not be illuminated through comparison with control participants alone. Within their work examining the processing of abstract as compared with concrete nouns, Cousins et al. (2017) compared production between individuals with the behavioural variant of frontotemporal degeneration and semantic dementia; pathologies chosen due to the locus of degeneration and the anticipated effect of this on concrete and abstract noun processing respectively. In terms of considering the effect of increasing selection demands particularly in PD, given the sensitivity of the comparison indicated in Cousins et al.'s (2017) study, comparing the performance of individuals with PD with that of individuals with semantic dementia in future may be elucidating.

Notably, including a group of younger adults in future studies may also be beneficial in understanding the effect of executive demands in language processing as part of typical ageing. Whilst not significant, findings would suggest that the effect of word-pair relatedness on dysfluency, across all participants, was sizeable, with a higher percentage of dysfluencies seen in sentences produced in response to loosely related word pairs. Previous studies (e.g. Crescentini, Lunardelli, et al., 2008), have looked solely at the ability to achieve the task, meaning there is no (as far as can be established) directly comparable prior research within which to embed and consider this finding. Interestingly, re-running the analysis with the control participants who showed altered performance at an individual level in a cognitive task removed actually slightly increased the size of the effect, whilst slightly reducing the (already small) effect size of the interaction. Including both a younger control group and, if sample size allows, subtyping according to performance within specific cognitive tasks, could help to unpick some of the patterns observed here.

In contrast to the measure concerned with the overall percentage of dysfluencies evident, average pause length was found to vary significantly between groups, with longer pauses evident in sentences produced by individuals with PD. This difference was not however found to be influenced by the degree of action associated with the verb and, importantly, was confined to sentences produced in response to picture stimuli. The fact that this effect was only observed in the task within which verb retrieval was required could indicate that increased pause length in the PD group was representative of delayed verb activation. The possibility remains too, however, that the presence of longer average pause lengths reflects altered visual integration and/or an alteration in utterance planning – although, the latter seems less likely, given findings from the current literature indicating that utterance planning in individuals with PD appears to proceed largely in line with that of controls (Lee, 2017). It is interesting, too, that this increase in pause length was not accompanied by an increase in the percentage of dysfluencies per utterance, suggesting that the increased pause length observed may have been compensatory in nature, allowing the sentence to proceed with a degree of fluency (as measured through the number of pauses, false starts etc.) equal to that of controls.

5.4.2 Lexical Content

Whilst a significant main effect of action and transitivity on utterance length and lexical density respectively was indicated, in neither instance was the finding corroborated by non-parametric analysis. Thus, findings overall demonstrated neither action nor transitivity, or the number of conceptual options elicited by a given word pair, to significantly influence either the length of sentences produced, or the lexical density of them. There was no difference in the pattern of performance between individuals with PD and controls, in contrast to the predictions made that the sentences of individuals with PD would be influenced by the characteristics of the verb around which the sentence was built.

The finding that, overall, there was no significant difference in average utterance length between individuals with PD and controls is in line with previous studies (e.g., Lee et al., 2019; Murray, 2000) utilising tasks with comparable degrees of constraint (i.e., not spontaneous speech samples). Thus, in that sense, this study adds to the body of evidence to suggest that utterance length is largely unaffected in PD, when cognitive and linguistic (including pragmatic) demands are constrained (i.e., when production is not spontaneous). Whilst the lack of a significant effect of the verb's characteristics on utterance length in PD goes against what was predicted, it is in line with the idea suggested in relation to measures of dysfluency that, when the processing of verbs is unaltered, sentence construction – as measured in this instance through utterance length – is similarly intact.

All that being said, whilst the significant main effect of action on utterance length in the sentence production task was not corroborated by necessary non-parametric analysis, the size of the effect was large and is therefore worthy of further consideration. One potential explanation for this trend is the (natural) difference in the degree of movement shown in the pictures in each action condition, and how much additional detail participants felt compelled to provide in relation to that. It may be the case that, because there was less going on (in terms of motion) in each picture in the low action condition, participants felt bound to provide more extraneous detail in order to fulfil what they had been asked to do and accurately describe the action they saw happening in the picture (in other words, because less overt action was being depicted, the importance of the surrounding etc. to the action itself was amplified). It is important to note too however that whilst again not being statistically significant, the interaction between action and group was again accompanied by a large effect size ($\eta_p^2 = .14$), with further exploration suggesting that, when the groups are considered separately, action had a noticeable (small-medium) effect ($d = 0.39$) only within the PD group.

It may be the case that, for the reasons just outlined, individuals with PD provided more information in relation to picture stimuli depicting low action scenes, making the effect more one of task than verb processing per se. On the other hand, it could reflect a specific effect in the PD group of verb action on sentence construction, with less said in response to high action verbs, perhaps due to increased processing demands. If this latter possibility was proven to be correct, this creates a number of further questions regarding why this effect seems to be confined to utterance length and not seen in other measures of sentence construction. It needs to be borne in mind however that, when the interaction was explored in detail, the size of the effect of action on utterance length in PD was fairly small and, as the data in Table 23 suggest, may not be noticeable or have a sizable effect in terms of functional communication. Nonetheless, there is certainly an indication that the effect of action on utterance length in PD may be worth exploring further with a larger sample size, particularly across different language tasks.

Previous research regarding the informativeness of production in PD is mixed, with some studies reporting a reduction in informativeness, as measured through the percentage of correct information units (Murray, 2000; Roberts & Post, 2018), and others not (Lee et al., 2019). As discussed in Section 1.2.4, a hypothesis proposed by the author to account for this difference – but one for which there was not the information available to either prove or disprove – is the potential confound of fluency. The measure of lexical density employed within this study is not directly comparable to the percentage of correct information units used in previous studies. Nonetheless, it is interesting that within this group of individuals with PD who did not show an alteration in the percentage of dysfluencies per sentence as compared with controls, no difference in lexical density was seen either. Additionally, whilst again the lack of any significant influence of a verb's action or grammatical complexity on lexical density in the PD group was not as predicted, the finding is in line with the proposal that when verb processing is intact, the lexical density of sentences produced is similarly unimpaired. It is important to re-emphasise here that the cognitive profile of individuals with PD included within this study was comparable to that of controls. Thus, the question as to whether subtle effects of a verb's characteristics on sentence construction may be seen – even if accuracy at a single word level is unimpaired – in the presence of cognitive alteration remains.

5.4.3 Response (Formulation) Time

The general pattern of results suggested there to be no difference in the time taken to formulate a sentence in the PD group, as compared with controls. The action and/or transitivity of the verb at the centre of the sentence had no influence on RT in either the PD or control group, in response either to a picture stimulus or given word. Where an effect on sentence formulation time was seen however was in the task concerned with word-relatedness. Across both groups, sentences were provided more quickly in response to highly related word-pairs, as compared with loosely related word-pairs. Previous studies conducting similar tasks (Crescentini, Lunardelli, et al., 2008) have not included a measure of RT, making it difficult to compare performance of this group of controls with that in other studies. Nonetheless, the overall pattern seen is not necessarily surprising, given the more limited and likely more immediate conceptual options arising from the highly related word-pairs. What is surprising, and goes against what was predicted, is that the differential between formulation time according to the number of conceptual options was of equal magnitude between individuals with PD and control participants. The finding would again appear however to be in line with the discussion put forward in relation to the percentage of dysfluencies seen, indicating that, in this group of individuals with PD, conditions expected to induce increased executive control demands had no impact on RT.

The fact that, in general, RT was comparable between individuals with PD and controls stands in some contrast to findings reported in the current literature. In their spontaneous speech tasks, both Illes (1989) and Huber and Darling (2011) observed a pattern of increased pause length in individuals with PD, prior to speech onset – a finding they discussed in relation to sentence planning. The findings here would suggest that no such deficit in planning exists when the sentences to be produced are independent from one another, are guided by external constraints (whether that be a picture, or a given word) and have a naturally occurring gap between them in the form of a key/mouse press to summon the next stimulus (see Figure 16 for a reminder of the task procedure utilised within this study). It may be the case, therefore, that any planning deficit seen in alteration reflects discourse related demands, whether they be cognitive or linguistic in nature (see Ellis et al., 2015 for discussion regarding narrative cohesion in PD).

Summary

In summary, with the exception of average pause length, no difference in sentence construction was evident in the PD group, as compared with controls. The difference in findings between this and previous studies (e.g., Troche & Altmann, 2012) was considered in relation to the cognitive profile of the PD group, the information available regarding verb processing ability and the nature of the tasks employed. The finding that average pause length was found to be longer in the sentences of individuals with PD, in response to picture stimuli, could potentially be reflective of delayed verb retrieval or reflect a compensatory strategy to maintain overall sentence fluency (as measured through the percentage of dysfluencies).

6 Language performance in Parkinson's Disease across tasks which differ in their nature and linguistic demands

6.1 Introduction

Within this chapter, the focus is on the effect of the nature of a linguistic task on language production in Parkinson's Disease (PD). This was considered along two separate lines. The first was concerned with investigating whether verb production accuracy in PD was influenced by whether the task was eliciting verb production in a single word or sentence context. The second was concerned solely with sentence level production, and whether the nature of the stimuli provided (e.g., whether it was a picture, or a given verb) had an influence on sentence construction. Sentence construction was considered using three measures: fluency, lexical content and the time taken to formulate a response, as measured through response time (RT). A reminder of the Research Question and sub-questions addressed, in the context of the overall research, are presented in Figure 24.

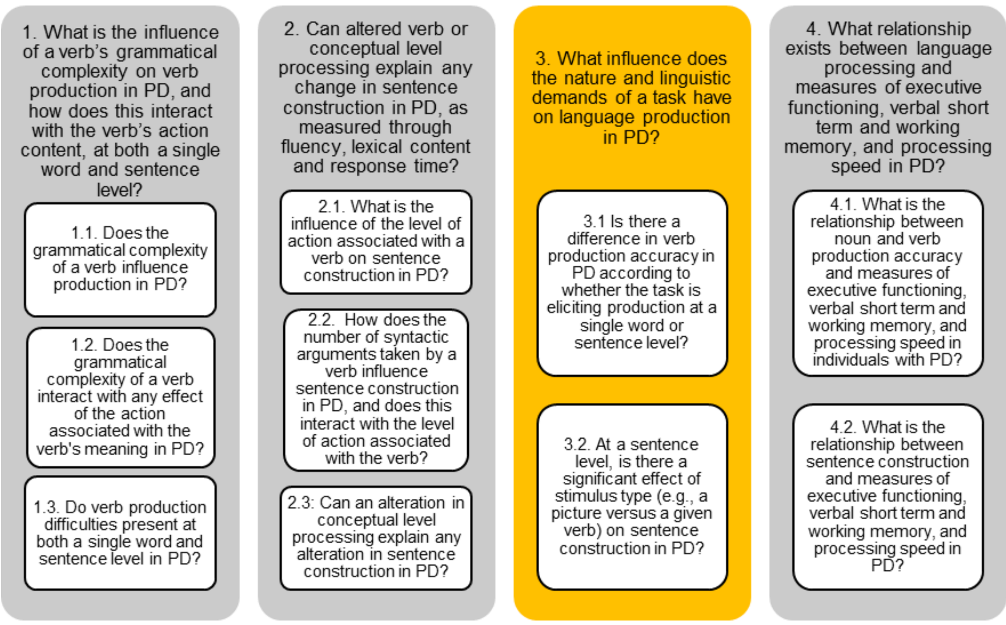

Figure 24. Research questions and sub-questions: focus on Research Question 3

As far as can be established, to date no experimental comparison of performance within different sentence production tasks by the same group of individuals with PD, or comparison of verb production in a sentence as compared with a single word context, has been conducted.

It was expected that, due to the increased cognitive demands, verb production in a sentence context would be more difficult for individuals with PD than that in a single word context. In terms of sentence construction, the hypothesis made started with the premise that verb – as compared with noun – retrieval would be altered in PD (e.g., Cotelli et al., 2007; Rodríguez-Ferreiro et al., 2009). Thus, by extension, it was anticipated that sentences produced in circumstances within which individuals had to retrieve a verb (i.e., in response to picture stimuli) would take longer to formulate, be shorter, of lower lexical density and less fluent than those within which individuals had been supplied with a verb, meaning that retrieval was not necessary. It was expected, too, that sentences produced in response to a single, given verb, would be more fluent than those produced in response to a given word-pair, due to the number of conceptual options elicited in this latter condition (Crescentini, Lunardelli, et al., 2008; Crescentini, Mondolo, et al., 2008). No effect of stimulus type, in either instance, was expected to be seen in the control group. A reminder of the hypothesis accompanying each sub-question is provided below:

RQ 3.1. Is there a difference in verb production accuracy in PD according to whether the task is eliciting production at a single word or sentence level?

> *Hypothesis: Verb accuracy will be reduced in a sentence as compared with a single word context, in the PD group.*

RQ 3.2. At a sentence level, is there a significant effect of stimulus type (e.g., a picture versus a given verb) on sentence construction in PD?

> *Hypothesis 1: Sentences provided by individuals with PD in response to a picture will be shorter, of lower lexical density, take longer to formulate and be less fluent than those produced in response to a given verb. No such effect will be evident in the control group.*
>
> *Hypothesis 2: Sentences created by individuals with PD, using a given word-pair, will be less fluent than those produced in response to a single verb. Again, no difference in the sentences produced according to stimuli type will be evident in the control group.*

It was not necessary to conduct any further tasks in order to obtain the information necessary for these analyses. Full details of the tasks from which information was gathered are provided in Table 30, housed in Section 6.2.1. Three separate comparisons were conducted, as summarised below:

1. To assess the influence of task on verb production, comparison was made between individuals' overall accuracy scores from the Verb Naming Task and Sentence Production Task
2. To look at the effect of stimulus type (picture stimuli as compared with a given verb) on sentence construction, measures of sentence construction gathered from the Sentence Production Task and One Word Sentence Generation Task were compared
3. To again look at the effect of stimulus type (the provision of one as compared with two words) on sentence construction, measures of sentence

construction gleaned from the One Word Sentence Generation Task and the Two Word Sentence Generation Task were compared

Following a brief methods section (Section 6.2) the results of the conducted analyses are presented (Section 6.3). The chapter closes with a discussion of these findings (Section 6.4).

6.2 Methods

A mixed factorial design was adopted for all investigations, with stimulus-type the within-subjects factor.

6.2.1 Materials and Procedures

Materials

Table 30 below serves as a reminder of the tasks utilised to gain the information required to conduct the analysis.

Table 30.

Tasks utilised to investigate the effect of task on verb production and sentence construction

Language Domain	Task(s)	Link to full task materials and procedure
Verb Production	Verb Naming Task	See Section 4.2.1
	Sentence Production Task	See Section 4.2.2
Sentence Construction	Sentence Production Task	See Section 5.2.1
	One Word Sentence Generation Task	See Section 5.2.2
	Two Word Sentence Generation Task	See Section 5.2.3

Procedures and Scoring

For full details of the procedures followed within each task, please see the appropriate section signalled in Table 30. To briefly summarise, within the Verb Naming and Sentence Production task, individuals were shown a picture and asked either to name the action depicted within it (Verb Naming Task) or describe it using a full sentence, using the additional sentence starter provided (Sentence Production Task). In the One Word and Two Word Sentence Generation tasks, individuals were either given a verb (One Word Sentence Generation Task) or a word-pair (Two Word Sentence Generation Task) and asked to produce a sentence using that given word/word-pair.

In all instances, data was collapsed across any previously utilised within-subjects factor(s) to create an overall performance score for each task.

6.3 Results

6.3.1 The effect of a single word vs sentence level production context on verb accuracy

To assess the influence of production context – i.e., the accuracy of verb production in a single word vs a sentence context – on verb accuracy, a 2 (group) x 2 (production context) mixed factorial ANOVA was conducted.

As with previous analyses concerned with data from the Verb Naming and Sentence Production Tasks, the datasets which had been adjusted to remove the potential confound of stimulus-led variability were utilised (see Section 4.3.1 and 4.3.2 for full detail). So that the stimuli lists were precisely comparable between datasets, any stimuli removed from the verb naming task dataset were similarly removed from the sentence production task dataset, and vice versa. This led 14 stimuli (‘chat’, ‘collide’, ‘sob’, tiptoe’, ‘stumble’, ‘swallow’, ‘sprinkle’, ‘unlock’, ‘bury’, ‘unload’, ‘donate’, ‘recycle’, ‘extinguish’ and ‘unload’) to be removed, creating a list totalling 42 stimuli. The data are outlined in Table 31.

Table 31.

Mean (SD) and median (IQR) verb accuracy scores, as a function of group and production context

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Accuracy (% Correct)	Single Word Context (Verb Naming Task)	71.0 (11.7) *75.0 (13.7)*	76.4 (9.24) *78.6 (11.9)*
	Sentence Context (Sentence Production Task)	68.5 (8.89) *69.0 (15.5)*	71.7 (11.7) *71.4 (25.0)*

No significant main effect of production context, $F(1,39) = 2.69$, $MSE = 93.9$, $p =.109$, $\eta_p^2 = .065$, group, $F(1,39) = 2.90$, $MSE = 126$, $p =.097$, $\eta_p^2 = .069$, or interaction between the variables, $F(1,39) = 0.24$, $MSE = 93.9$, $p =.629$, $\eta_p^2 = .006$, was evident. Note, data for the ANOVA did not meet all necessary assumptions.

Findings show that the context within which individuals were asked to provide a verb – i.e., within a single word vs a sentence context – did not significantly influence accuracy, in either the PD or control group. There was neither any difference in overall verb accuracy, collapsed across both tasks, between individuals with PD and controls.

6.3.2 The effect of stimulus type on sentence construction

Analysis conducted to examine the effect of stimulus type on measures of sentence construction was primarily concerned with comparing sentences produced in response to picture stimuli and those produced in response to a given word. As such, performance within all three sentence construction measures – fluency, lexical content and RT – from the Sentence Production (picture stimuli) and One Word Sentence Generation Tasks (given word) were compared. In all instances, the dataset from the Sentence Production Task adjusted for the potential confound of stimulus-led variability was utilised (see Section 4.3.1 and 4.3.2 for full detail). So that the stimuli lists were precisely comparable between datasets, any stimuli removed from the Sentence Production Task dataset were similarly removed from the Sentence Generation Task dataset. 11 verbs were removed from the dataset (‘scowl’, ‘stumble’, ‘collide’, ‘tiptoe’, ‘sob’, ‘donate’, ‘swallow’, ‘recycle’, ‘sprinkle’, ‘extinguish’, and ‘unload’), creating a list of 45 verbs.

Additionally, the fluency of sentences produced in response to a single given word (One Word Sentence Generation Task), and those produced in response to a word-pair (Two Word Sentence Generation Task) were also compared.

6.3.2.1 The effect of stimulus type on fluency

The influence of stimulus type on both sub-measures of fluency – i.e., the percentage of dysfluencies (as measured through the collective percentage of pauses, false starts/restarts, verbal fillers which appeared within the sentence, word repetitions and sound repetitions) and average pause length – was considered. First presented is analysis concerned with comparing sentences produced in response to a picture stimulus with those produced in response to a given verb. This is followed by findings from the comparison made between sentences produced in response to one as compared with two provided words. In each instance, two, 2 (group) x 2 (stimulus type) mixed factorial ANOVAs were conducted (one per fluency sub-measure) with Bonferroni correction for multiple comparisons applied (adjusted α =.025).

6.3.2.1.1 Comparison of the fluency of sentences produced in response to a picture and a given verb

One control participant was excluded from the analysis, due to having misunderstood the One Word Sentence Generation Task (*n* = 40). The data are provided in Table 32.

Table 32.

Mean (SD) and median (IQR) fluency scores, as a function of stimulus type (picture stimuli vs given verb) and group

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Dysfluencies (% Score)	Picture Stimuli (Sentence Production Task)	10.9 (5.80) *9.68 (8.33)*	10.1 (8.25) *7.28 (8.89)*
	Verb Provided (One Word Sent. Generation Task)	8.78 (7.48) *6.95 (5.77)*	6.02 (4.87) *5.06 (5.57)*
Pause Length (ms)	Picture Stimuli (Sentence Production Task)	775 (201) *758 (277)*	598 (180) *554 (197)*
	Verb Provided (One Word Sent. Generation Task)	672 (198) *610 (192)*	633 (166) *566 (263)*

From the analysis concerned with the percentage of dysfluencies evident (adjusted α =.025) a significant effect of stimulus type was shown, $F(1,38) = 7.53$, MSE = 24.4, $p = .009$, $\eta_p^2 = .17$. Collapsed across groups, a greater percentage of dysfluencies was evident in sentences produced in response to a picture ($EMM_{Picture}$ = 10.5, $SE_{Picture}$ = 1.19; $EMM_{VerbProvided}$ = 7.40, $SE_{VerbProvided}$ = 0.97). No significant main effect of group, $F(1,38) = 0.90$, MSE = 66.6, $p = .348$, $\eta_p^2 = .023$, or interaction, $F(1,38) = 0.78$, MSE = 24.4, $p = .383$, $\eta_p^2 = .020$, was evident. Because data for both the ANOVA and within-subjects comparison (stimulus type) failed the assumption of normality, a Sign test was conducted to substantiate presence of a significant main effect of task. Findings supported presence of such an effect, $z = 3.95$, $p < .001$, r = 0.62.

When considering pause lengths (adjusted α =.025), a significant main effect of group was evident, $F(1,38) = 6.96$, MSE = 32193, $p = .012$, $\eta_p^2 = .16$, with longer pause lengths evident in the PD group, collapsed across tasks (EMM_{PD} = 724ms, SE_{PD} = 31.7ms; $EMM_{Control}$ = 616ms, $SE_{Control}$ = 25.9ms). Neither a main effect of stimulus type, $F(1,38) = 0.65$, MSE = 35548, $p = .426$, $\eta_p^2 = .017$, nor significant interaction between stimulus type and group, $F(1,38) = 2.58$, MSE = 35548, p = .117, $\eta_p^2 = .064$, presented. A Mann-Whitney U test was run due to both data for the ANOVA and between groups comparisons failing to meet all necessary assumptions. This corroborated the main effect of group on pause length, collapsed across sentence construction tasks, $U = 97.0$, $p = .008$, $r = 0.41$.

Summary of Results

Across all participants, sentences produced in response to a picture were found to contain a significantly greater percentage of dysfluencies than those produced in response to a given verb. This same effect was not however seen in the analysis considering pause lengths. Collapsed across both tasks, group was found to have a significant main effect on pause length, with average pauses found to be longer in the sentences produced by individuals in the PD group.

6.3.2.1.2 Comparison of the fluency of sentences produced in response to a single verb vs a word-pair

One participant was excluded from both analyses, due to having misunderstood both tasks (*n* = 40). For the analysis concerned with pause length, two further individuals were necessarily excluded due to having no example pauses within a condition; thus, for the latter analysis exploring pause length, the sample size was 38. The data are provided in Table 33.

Table 33.

Mean (SD) and median (IQR) fluency scores as a function of stimulus type (one verb vs a given word-pair) and group

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Dysfluency (% Score)	One Word Sentence Generation Task	8.86 (6.42) *6.95 (5.88)*	6.64 (5.06) *4.95 (5.11)*
	Two Word Sentence Generation Task	11.7 (7.58) *10.3 (13.9)*	6.87 (5.69) *5.56 (4.25)*
Pause Length (ms)	One Word Sentence Generation Task	647 (137) *622 (205)*	601 (166) *584 (235)*
	Two Word Sentence Generation Task	657 (236) *654 (256)*	605 (281) *550 (331)*

Analysis (adjusted α =.025) indicated no significant main effect of stimulus type, $F(1,38) = 3.41$, $MSE = 13.4$, $p = .073$, $\eta_p^2 = .082$, or group, $F(1,38) = 3.96$, $MSE = 60.7$, $p = .054$, $\eta_p^2 = .094$, on the percentage of dysfluencies per utterance. No significant interaction was evident, $F(1,38) = 2.48$, $MSE = 13.4$, $p = .124$, $\eta_p^2 = .061$. Note, data for the ANOVA did not meet all necessary assumptions.

Analysis concerned with average pause length (adjusted α =.025) showed no main effect of stimulus type, $F(1,36) = 0.028$, $MSE = 32821$, $p = .867$, $\eta_p^2 = .001$, group, $F(1,36) = 0.71$, $MSE = 61287$, $p = .405$, $\eta_p^2 = .019$, or significant interaction, $F(1,36) = 0.007$, $MSE = 32821$, $p = .936$, $\eta_p^2 = .000$. Note, data for the ANOVA failed the assumption of normality.

In sum, there was no difference in the fluency of sentences – as measured both through the percentage of dysfluencies and average pause length – produced in response to a given verb as compared with a word-pair, across all participants. Collapsed across stimulus type, no difference in sentence fluency existed between individuals with PD and controls.

6.3.2.1.3 Overall Summary of Results (Fluency)

Collapsed across group, sentences produced in response to picture stimuli contained a significantly greater percentage of dysfluencies than those produced in response to a given verb. No such difference existed in sentences produced in response to a given verb, as compared with a word pair. When average pause length was considered a significant main effect of group emerged, with longer pause lengths evident in the PD group. This effect only appeared collapsed across sentences provided in response to a picture and a given verb (the same pattern was not evident collapsed across the one and two word sentence generation tasks) however, suggesting that average pause length in sentences produced in response to picture stimuli may have been weighting the finding.

6.3.2.2 The effect of stimulus type on lexical content

The influence of stimulus type on two of the three lexical content sub-measures were considered: utterance length and lexical density. For both sub-measures, 2 (group) x 2 (stimulus type) mixed factorial ANOVAs were utilised, with Bonferroni correction for multiple comparisons applied (adjusted $\alpha = .025$). Comparisons were made between responses given in response to a picture (sentence production task) and those given in response to a given word (one word sentence generation task). The dataset adjusted as outlined within the previous section (Section 6.3.2.1) was utilised for the analysis.

6.3.2.2.1 Comparison of the lexical content of sentences produced in response to a picture and a given verb

One control participant was removed from both analyses, due to misunderstanding the one word sentence generation task ($n = 40$). An additional control participant was excluded from analysis conducted on the lexical density data, due to continual initial determiner omission. Thus, for the latter analysis, the sample size was 39. The data are outlined in Table 34.

Table 34.

Mean (SD) and median (IQR) lexical content scores as a function of task (sentence production and one word sentence generation tasks) and group

		PD	Control
		Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Utterance Length	Sentence Production Task	7.98 (1.76)	8.25 (3.29)
		7.51 (1.36)	*6.80 (3.43)*
	One Word Sentence Generation Task	6.84 (1.75)	6.21 (1.19)
		6.46 (2.43)	6.06 (1.95)
Lexical Density (% Content Words)	Sentence Production Task	48.2 (1.39)	48.3 (1.83)
		48.1 (1.59)	*48.7 (3.09)*
	One Word Sentence Generation Task	48.2 (4.01)	50.9 (7.25)
		47.1 (6.39)	*49.4 (4.72)*

Analysis (adjusted α = .025) revealed a significant main effect of stimulus type on utterance length, $F(1,38) = 13.7$, $MSE = 3.54$, $p = .001$, $\eta_p^2 = .27$. Collapsed across participants, longer utterances were provided in response to picture stimuli ($EMM_{Picture} = 8.12$, $SE_{Picture} = 0.45$; $EMM_{VerbProvided} = 6.53$, $SE_{VerbProvided} = 0.23$). Further exploration of the data indicated clausal and phrasal word errors to be low in both tasks and comparable in their percentages ($M_{Picture} = 0.60$, $SD_{Picture} = 0.79$; $M_{VerbProvided} = 0.97$, $SD_{VerbProvided} = 4.05$) thus making it unlikely that any difference in utterance length between tasks was attributable to differences in word omissions. No other main effect or interactions were significant (all $p > .30$). Because data for neither the ANOVA nor within-subjects comparison (stimulus type) met all necessary assumptions, a non-parametric Sign test was additionally run. This analysis supported the significant main effect of task, on utterance length, $z = -3.32$, $p = .001$, $r = 0.52$.

For lexical density (adjusted $\alpha = .025$), no significant main effect of stimulus type, $F(1,37) = 1.42$, $MSE = 21.7$, $p = .240$, $\eta_p^2 = .037$, group, $F(1,37) = 1.99$, $MSE = 18.9$, $p = .167$, $\eta_p^2 = .051$, or interaction, $F(1,37) = 1.58$, $MSE = 21.7$, $p = .217$, $\eta_p^2 = .041$, was evident. Note, data for the ANOVA did not meet all necessary assumptions.

6.3.2.2.2 Overall Summary of Results (Lexical Content)

Across all participants, longer utterances were produced in response to picture stimuli, as compared with a given verb. This did not appear attributable to any difference in word omissions, per task condition. Stimulus type had no significant influence on lexical density, across participants.

6.3.2.3 The effect of stimulus type on response time

RT was compared between sentences produced in response to a picture (sentence production task) and sentences produced in response to a written verb (one word sentence generation task). The dataset adjusted as outlined within Section 6.3.2.1 was utilised for the analysis.

6.3.2.3.1 Comparison of the RT of sentences produced in response to a picture and a given verb

A 2 (group) x 2 (task) mixed factorial ANOVA was conducted to investigate the effect of stimulus type on RT. Due to one participant being excluded from the one word sentence generation task, $n = 40$ for this analysis. The data are provided in Table 35.

Table 35.

Mean and median RT (ms) scores, as a function of task (sentence production and one word sentence generation tasks) and group

	PD	Control
	Mean (SD) *Median (IQR)*	Mean (SD) *Median (IQR)*
Sentence Production Task (ms)	2229 (688) *2107 (1090)*	2223 (1262) *1908 (997)*
One Word Sentence Generation Task (ms)	2543 (1013) *2289 (1300)*	2330 (815) *2294 (1075)*

No significant main effect of stimulus type, $F(1,38) = 1.86$, $MSE = 456910$, $p = .181$, $\eta_p^2 = .047$, or group, $F(1,38) = 0.15$, $MSE = 1501125$, $p = .697$, $\eta_p^2 = .004$, on RT was evident. There was no significant interaction between the variables, $F(1,38) = 0.45$, $MSE = 456910$, $p = .508$, $\eta_p^2 = .012$ Note, data for the ANOVA did not meet all necessary assumptions.

6.3.2.3.2 Overall Summary of Results (Response Time)

Stimulus type was not found to have a significant effect on RT. Collapsed across both tasks, the time taken to formulate a sentence (as measured through RT) was not found to significantly differ between groups.

6.4 Discussion

Of focus within this analysis was the impact of two factors – production context and stimulus type – on verb production and sentence construction, respectively. It was anticipated that this analysis may, in part, build upon and formally investigate patterns observed within the exploration concerned with previous research questions. In contrast to the analysis outlined in previous chapters however, of sole interest within this chapter was the influence of task – whether that be in relation to production context, or stimulus type. Findings relating to verb production will first be discussed, followed by those relating to sentence construction.

6.4.1 Verb Production

There was no significant difference in the pattern of verb production performance between individuals with PD and controls. Across both groups, verb production accuracy was comparable in a single word as compared with a sentence context. This was as predicted for the control group but not what was expected to be seen in the PD group, where presence of reduced performance in a sentence context, due to the increased cognitive demands, had been anticipated. To the author's knowledge, this is the first study to compare verb production performance in PD in a single word and sentence context. There is, therefore, no directly comparable prior evidence within which to embed and consider these findings. Nonetheless, they will be considered in relation to prior research which has considered the cognitive load of the language tasks employed.

Previous work conducted by Vanhoutte et al. (2012) indicated that, when cognitive demand was kept low, sentence construction – in terms of utterance length and the grammaticality of sentences – was comparable between individuals with both early and advanced PD, and control participants. Further however, and of particular relevance here, was the finding that in this condition of low cognitive demand, individuals at a more advanced stage of PD showed altered verb use – as reflected through a reduced diversity in the verbs used – whilst those at an earlier disease stage did not. This would suggest that, in conditions of low cognitive demand, impairments in verb processing in a high level (in this instance, discourse) context may not appear in the earlier stages of PD but may become apparent later in the disease course.

Individuals within this study were not grouped according to disease duration, with average disease duration in the whole PD group (6.98 years) sitting between the early (4.7 years)[14] and advanced (11.4 years)[14] stage groups reported within Vanhoutte et al.'s (2012) study. Nonetheless, and bearing in mind Vanhoutte et al.'s (2012) findings, the pattern of performance seen within this study could lead to the very tentative proposal that, in the earlier stages of PD, increased cognitive demands do not translate to a greater degree of verb processing impairment. It must be stressed however that the finding reported here is confined to a group of individuals with PD who, as well as being in a relatively early stage of PD (as considered in terms of disease duration), were not found to show altered cognitive performance in any of the domains measured, or to show altered verb processing at a single word level.

Furthermore, the stage of PD was only able to be compared and considered here in relation to disease duration. Whilst MacMahon et al. (1999, cited in Thomas & MacMahon, 2004) provide useful information regarding the average duration spent in each stage, there is, unsurprisingly, significant variability within each stage such that it cannot be assumed with any certainty that an individual with a certain disease duration will fall within a particular stage. It would be interesting to explore in future studies whether there is a difference in verb processing performance according to cognitive load when all of these variables – i.e., disease stage, single word verb naming ability and general cognitive abilities – are manipulated.

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[14] Note, figures reported exactly as provided within the cited material (Vanhoutte et al., 2012).

The potential exists, too, that no difference between single word and sentence level processing was seen in this study because the cognitive demands of the sentence production task were kept relatively low, through the inclusion of a sentence starter (provided to steer participants towards the target action; see Section 2.3.4). It should be reiterated too that performance within each of the cognitive domains measured within this study, as well as general cognitive functioning, was not found to be significantly different between the PD group and controls. Thus, the lack of any effect of increased cognitive load could as equally be a reflection of the cognitive profile of this group of individuals with PD.

6.4.2 Sentence Construction

The primary comparison of interest, here, was between the construction of sentences produced in response to a given picture (as in within the Sentence Production Task) and those produced in response to a given verb (as in the One Word Sentence Generation task). Or, to frame it another way, situations within which the verb at the centre of the sentence had to be retrieved but contextual, pictorial information was provided, versus one where the verb did not need to be retrieved, but no contextual information was provided. If, as was hypothesised, sentence construction would be negatively affected in PD when verb retrieval was required, reduced performance in the sentence production as compared with the one word sentence generation task would be expected. If, however, verb retrieval did not significantly influence sentence construction but the additional cognitive demands resulting from reduced contextual information provision did, reduced performance in the one word sentence generation, as compared with the sentence task, would be expected.

Additional comparison was made between sentences produced in response to a given verb, versus those provided in response to a given word-pair. This comparison, however, was confined to one measure of sentence construction: fluency.

6.4.2.1 Fluency

No difference in the pattern of dysfluencies evident in sentences produced in response to picture stimuli as compared with a given verb was evident between the two groups. Across all participants, a higher percentage of dysfluencies were found to be present in sentences produced in response to a picture. This finding is interesting to consider in relation to two studies discussed in the theoretical background: the first conducted by Huber and Darling (2011) and the second by Troche and Altmann (2012). These studies diverged in their findings regarding the presence of greater sentence dysfluency in PD; a fact which, within the theoretical background, was considered in relation to the way dysfluencies were measured (see Section 1.2.4). It is worth considering the possibility too, however, that the difference may also have reflected a difference in the nature of the tasks employed.

Specifically, Troche and Altmann (2012), who did report reduced fluency, utilised a task within which individuals were asked to produce a sentence in response to a given picture, whilst Huber and Darling (2011), who saw no significant difference in the number of dysfluencies evident in sentences produced by individuals with PD, used a spontaneous speech task. Whilst the task utilised by Huber and Darling (2011) is clearly not directly comparable to the one word sentence generation task utilised within this study, the overall pattern seen here could be interpreted as being in line with the aforementioned pattern of results – i.e., that a greater percentage of dysfluencies is evident in PD in sentences that are produced in response to a picture as compared with those that are not. It should of course be stressed that performance within the tasks conducted by Huber and Darling (2011) and Troche and Altmann (2012) were not formally compared, thus it is impossible to establish if the indicated difference in performance would have been statistically significant. Regardless, the clear difference presenting in the findings of this study, is that the pattern observed was not just seen in the PD group.

The fact that there was no difference in the pattern of performance between individuals with PD and controls in this study goes against that which was predicted. However, when the finding is considered more broadly in terms of the pattern of linguistic performance shown by this group of individuals with PD, and the information around which the hypothesis was built, the finding in fact appears less surprising. As outlined in Section 6.1, sentences which required verb retrieval were hypothesised to be less fluent in PD, due to the anticipated presence of altered verb retrieval. In actuality, this group of individuals with PD did not show altered verb retrieval, as compared with controls. Thus, what this finding in effect indicates is that, when verb production is not found to be impaired in PD, a greater reduction in sentence fluency within situations in which verb retrieval is required is not witnessed either. Thus, whether such an outcome would be seen in a group of individuals with PD who did show an impairment of verb retrieval remains an open question.

To determine whether there may be other potential explanations to account for this finding, it is useful to first consider why the pattern seen may have emerged across all participants, including controls. One possibility is that the pattern represents differences in sentence planning demands between the tasks (according to the stimuli utilised). Whilst in both tasks, individuals were asked to provide a sentence only once the whole sentence had been formed, there was a much greater tendency in the sentence production task (requiring individuals to provide a sentence in response to a picture) for all individuals (both individuals with PD, and controls) to begin speaking and then stall, change tack, or pause before adding additional detail – a pattern suggestive of and in line with the incremental planning observed by Lee (2017). In contrast, it seemed that sentences provided in the one word sentence generation condition were largely planned in their entirety, before being said aloud.

Another possibility is that the difference seen, according to task, represents participants' certainty of the target being aimed for. The picture stimuli presented a greater degree of uncertainty – and, by extension, choice – not only in terms of the verb that could be used to describe the scene being observed, but in relation to the amount of additional information which could be utilised within the sentence. Add into that mix, too, the potential impact of participants' awareness of what was being 'tested' in this task – i.e., their ability to accurately describe what was going on in the picture – and it is perhaps unsurprising that sentences produced in this context were less fluent.

Bearing these two aspects in mind, the possibility arises that the equivalence of performance between the PD and control group may also reflect the cognitive profile of this particular PD group. It was hypothesised that, whilst the one word sentence generation task would place increased broader cognitive demands due to the lack of contextual information, the overall demands of verb retrieval would have a greater impact in PD. Thus, it was expected that sentences which required verb retrieval would be less fluent, shorter and of lower lexical density than those which did not. If the reverse pattern was seen however this could indicate either that the impact of broader cognitive demands outweighed those of verb retrieval in PD or – if verb retrieval was shown to be unimpaired – that an effect of broader cognitive demand is evident when verb retrieval is intact.

What this did not contemplate however was any difference between the tasks in terms of the number of conceptual options (at the message level) that may be evoked. It is plausible that, in the event, the picture stimuli may actually have created more options than a given verb, in turn incurring additional executive control demands. Thus, whilst the provision of contextual information may have reduced broader cognitive demands, selection demands may actually have increased. Whether, therefore, in a group of individuals with PD who showed altered cognitive performance, the effect of stimulus type may have been heightened, such that the difference in performance seen according to stimulus type was proportionally greater in the PD group, is interesting to consider. Further, how this presents – e.g., how any influence of selection demands according to stimulus type may interact with the concurrent difference in broader cognitive demands – would again be interesting to investigate in future studies.

A difference in performance between the PD and control group was seen when average pause length was considered, with pause length shown to be significantly longer in the PD group. This effect however did not interact significantly with task suggesting that, whilst pause lengths across the board were longer in PD, pause length was not influenced by differences in the demands placed by the tasks, according to stimulus type. This finding adds further weight to the proposal put forward in Section 5.4.1 that increased pause length in PD may reflect a compensatory strategy employed to allow sentences to proceed in manner equivalent to that of controls. What is less clear is why that compensation may be required. The analysis conducted in the previous chapter would suggest that, in this group of individuals with PD (bearing in mind their cognitive profile) increased pause length is not linked to the semantic or lexical-syntactic characteristics of the verb and the findings discussed in this chapter would suggest that it is not confined to situations within which verb retrieval is required, either.

The lack of a significant interaction between task and pause length in the PD group was also somewhat surprising given that, in the previous chapter concerned with examining the influence of a verb's characteristics on fluency, pause length was only found to be significantly longer, as compared with controls, in the sentence production task (i.e., when verb retrieval was required). Key differences between this and the previous analysis may explain the apparent difference, however. Because the only variable of interest – besides group – in this analysis was stimulus type, none of the within-subjects factors considered in the previous analysis were entered into the model. Further, because the influence of the characteristics of the verb were not under investigation, all sentences produced were included in this analysis; including those within which the target verb had not been used.

6.4.2.2 Lexical Content

Again, whilst utterance length was found to be influenced by task, this influence did not vary according to group, with the same pattern evident both in individuals with PD and controls. Across the board, sentences produced in response to picture stimuli (i.e., those produced in the sentence production task) were longer than those produced in response to a given verb – a finding which did not appear to be attributable to any difference in the occurrence of word omissions. As alluded to in the previous paragraphs, there has not been, as far as can be established, any formal comparison of performance in different linguistic tasks in PD, meaning that there is no direct previous evidence within which to embed these findings. That being said, the fact that there was no main effect of group would suggest that, in both of these constrained tasks (i.e., within which the possible verb and broader topic which could be covered was limited and, importantly, there was not a communicative partner) utterance length was comparable to that of controls does appear to be in line with previous findings reported within the literature (e.g., Dick et al., 2018 - see Section 1.2.4 for full discussion).

The lack of any significant interaction between group and task was not as predicted, with it expected that utterance length would be shorter in the condition within which verb retrieval was required, in the PD group. There was not expected to be any effect of task in the control group – a reflection primarily of the fact that the effect of task was expected to reflect verb processing difficulties, which were not expected to be present in controls. However, given the increased context provided to all participants in the picture stimuli condition, with hindsight it perhaps should have been expected that more would likely be said in the picture stimuli condition in controls, leading to observed increased utterance length in this condition.

Whilst the picture stimuli provided a set degree of detail – the amount of which to describe was up to the individual – the amount of information that each individual could use when creating a sentence from a given verb was entirely open. Further, there was no particular incentive to say more, as opposed to less, in this latter condition. In the sentence production task, individuals were asked to describe the action they saw taking place in the picture and may therefore have interpreted that, to complete the task as successfully as possible, they should include as much of the detail provided in the picture as possible. In contrast, because there were no bounds in the one word sentence generation task and nothing in the instructions to suggest that producing a longer sentence would be advantageous, there were no real overt factors motivating participants to do so. It may be the case too that, in an effort to 'say the sentence as soon as possible once it had been thought of', participants avoided spending the extra time which may have been required to form a longer sentence with the given verb as compared with the picture stimuli condition.

In accord with the discussion presented in the previous paragraphs considering sentence fluency, whilst the findings relating to both utterance length and lexical density in the PD group were not as predicted, they are actually in line with the principle underpinning the hypothesis. It was expected that, due to altered verb processing in PD, sentence conditions within which verb retrieval was required would result in reduced sentence length and reduced lexical density. The group of individuals with PD in this study did not however show altered verb processing at a single word level and, equally, did not show altered sentence construction in situations within which verb retrieval was required, as opposed to those within which it was not. Thus, in that sense, the findings are as would be expected, given the verb processing abilities of the PD group.

6.4.2.3 Response (Formulation) Time

No significant difference in RT existed according to stimulus type. Again, this pattern of performance was seen across all participants, with individuals with PD showing the same pattern of performance as controls. These findings would suggest that a requirement for verb retrieval in this group of individuals with PD did not translate to increased sentence formulation time – as might have been expected, had a specific verb production deficit presented. Thus, the same question as to whether this pattern may be reversed, had a specific verb retrieval been evidenced, remains open. These findings somewhat point away, too, from any effect of delayed semantic activation – whether that be via visual (picture stimuli) or linguistic (word stimuli) means – on sentence construction in the PD group. Had such an effect presented, either differentially according to stimulus type or across the board, sentence formulation time would have expected to have increased in the PD group; an effect which was not seen.

Summary

Overall, the findings discussed here would suggest that, when verb production is intact in individuals with PD, no effect of verb retrieval demands on sentence construction – as measured through sentence fluency, response (formulation) time and measures of lexical content – are observed. The findings could also reflect the cognitive profile of this group of individuals with PD, who performed comparably to controls in all cognitive measures. Whether different patterns of performance are seen in individuals with PD who are showing cognitive alteration would be interesting to manipulate and compare in future studies.

7 The relationship between measures of verb and noun production accuracy, sentence construction and core cognitive abilities

7.1 Introduction

The investigation outlined within this final experimental research chapter was concerned with understanding more about the underpinnings of any observed language changes in Parkinson's Disease (PD). Specifically of interest was the relationship between performance within the measures of executive functioning, verbal short term and working memory and processing speed outlined within the General Linguistic and Cognitive Profile, and measures of verb and noun production accuracy, and sentence construction. Correlational analyses were conducted to establish the relationship(s) between these variables of interest both in individuals with PD and controls. The research question and sub-questions addressed are provided in Figure 25.

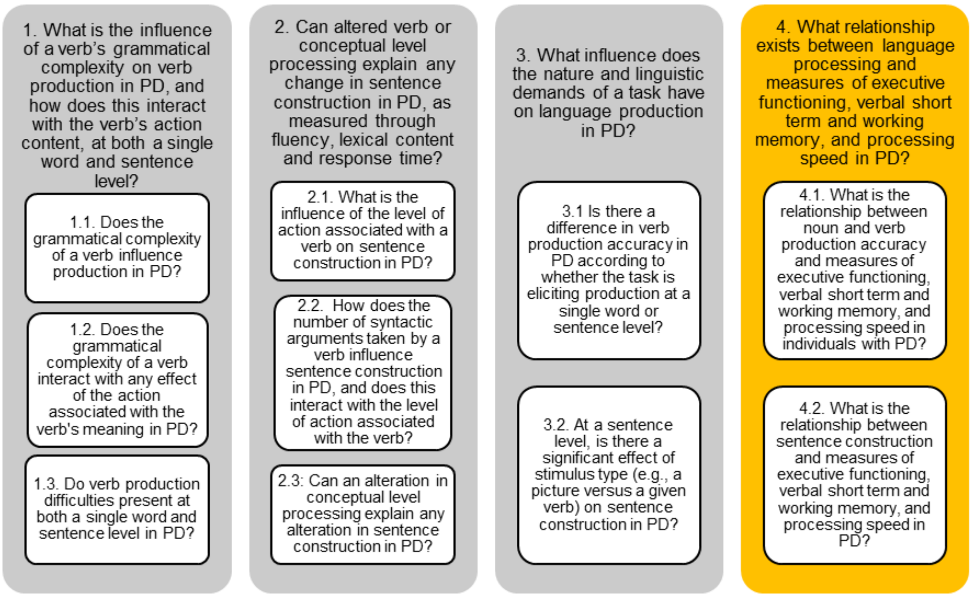

Figure 25. Research questions and sub-questions: focus on Research Question 4

From the limited information available within the current literature, it was anticipated that, in the PD group, relationships between both noun (Bocanegra et al., 2015; Crescentini, Mondolo, et al., 2008) and verb production (Crescentini, Mondolo, et al., 2008) and measures of executive functioning and working memory would be evident. No prediction was made regarding the relationship between verb and noun production and any cognitive ability in the control group.

With regards to sentence construction, whilst from the information available it was anticipated that, in the PD group, relationships between the measures of sentence construction and cognitive ability would appear (e.g., Murray, 2000; Troche & Altmann, 2012), specific predictions regarding between exactly which core cognitive abilities and sentence construction measures such relationships may present were not made. Similarly, in the control group, no prediction was made regarding whether any such relationships would emerge, and what pattern they might follow. A reminder of the hypothesis for each sub-question is provided below:

RQ 4.1. What is the relationship between noun and verb production accuracy and measures of executive functioning, verbal short term and working memory, and processing speed in individuals with PD?

> *Hypothesis: Relationships between verb and noun production and measures of executive functioning and working memory (i.e., storage and manipulation of information) will be evident in the PD group. No prediction is made regarding relationships between noun and verb production and cognitive ability in the control group.*

RQ 4.2. What is the relationship between sentence construction and measures of executive functioning, verbal short term and working memory, and processing speed in PD?

> *Hypothesis: Relationships between measures of sentence construction and core cognitive abilities will be evident in the PD group. No prediction regarding the relationship between core cognitive abilities and sentence construction in the control group has been made.*

Information for the correlational analysis was drawn from performance within tasks already conducted for the purpose of the General Linguistic and Cognitive profile, and tasks utilised to obtain data for analyses relating to previous research questions. The tasks from which the information was gathered, alongside a signpost to the relevant section within which a full description of the materials and procedures followed in the corresponding task can be found, is provided in Section 7.2.1 below. Analyses were concerned with relationships between the following variables:

1. Noun production accuracy and all cognitive measures
2. Verb production accuracy – at both a single word and sentence level – and all cognitive measures
3. The fluency, lexical content and response times (RTs) of sentences produced in response to picture stimuli, and all cognitive measures
4. The fluency, lexical content and RTs of sentences produced in response to a given verb, and all cognitive measures

A brief methods section (Section 7.2) is followed by findings from the correlational analyses, accompanied by a summary of the findings (Section 7.3). The chapter then closes with an overall discussion of the findings (Section 7.4).

7.2 Method

A correlational design was adopted to explore the relationship between language performance and the cognitive abilities of interest. Correlation was favoured as it is more appropriate for small sample sizes than regression. It is not able to provide as much information regarding the predictive value of core cognitive abilities on language outcomes, but nonetheless serves as a good indicator of where/whether relationships exist between variables and can therefore assist in guiding the focus of future investigations.

7.2.1 Materials and Procedure

Materials

See Table 36 below for an overview of the tasks employed. A full description of the materials and illustration of the procedures followed in each task can be found in the specified sections.

Table 36.

Tasks from which information was obtained for the correlational analysis

	Language/Cognitive Doman	Task(s)	Task materials and procedure
Language	Noun Production	Noun Naming Task	Section 3.2.3
	Verb Production	Verb Naming Task	Section 3.2.4 & 4.2.1
	Sentence	Sentence Production Task	Section 4.2.2
	Construction	Sentence Production Task	Section 5.2.1
		One Word Sent. Generation Task	Section 5.2.2
Cognitive	Set Shifting	Shifting Task	Section 3.2.5.1
	Inhibition	Stroop Task	Section 3.2.5.2
	Updating	2-back Task	Section 3.2.5.3
	Short Term &	Digit Span Forwards	Section 3.2.5.4
	Working Memory	Digit Span Backwards	
	Processing Speed	Inspection Time Task	Section 3.2.5.5

Procedures and Scoring

Performance accuracy in all tasks was collapsed across all within-subjects factors, such that an individual's overall 'score' from whichever domain was in question formed the basis of the correlation.

7.3 Results

7.3.1 The relationship between cognitive performance, word production in a single word and sentence context and sentence construction measures

For each group, correlations were run to explore the relationship between the measures of verb and noun production and sentence construction, and all cognitive measures. In all instances where it was applicable, the datasets adjusted for the potential confound of stimulus-led variability were utilised (for full detail of the process of adjustment for the noun naming, verb naming and sentence production datasets, see Section 3.3.3, Section 4.3.1 and Section 4.3.2, respectively). Spearman's Ranked-Order Correlation was utilised due its suitability for data between which no linear relationship is evident, and/or which fails the assumption of normality. Some high-level predictions were made regarding the presence of a relationship between language and other cognitive processing in the PD group (see Section 7.1), however because the tasks employed here tapped more specifically into the executive processes of interest than previous studies (e.g. Bocanegra et al., 2015), predictions regarding between which specific cognitive and language processes relationships would be seen were not made. Further, no specific prediction was made regarding any relationship(s) between performance in any of the separate language tasks. The correlational analysis conducted was consequently viewed as exploratory, with the intention being to highlight potential relationships which, for conclusions to be drawn, would then need to be followed up in future higher powered studies.

In line with those aims, alpha remained unadjusted at .05. However, in order to provide some indication which, of any, significant correlations may be most meaningful, correction was also applied in the form of the Benjamini-Hochberg procedure and reported accordingly. The Benjamini-Hochberg procedure was performed using a spreadsheet devised by McDonald (2014) with the false discovery rate (FDR) set at 5%. All findings are presented in Table 37 (PD Group) and Table 38 (Control Group), with values which remained significant following application of the Benjamini-Hochberg procedure marked with an underscore.

Table 37.

Relationship between word production accuracy, sentence constructions measures and cognitive abilities in the PD group

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Noun Accuracy		**.71****	.48	-.29	-.30	-.46	-.16	.12	-.033	0.22	.20	.20	-.24	.034	.030	.35	-.23	.21	-.17
2. Verb Accuracy			.37	-.003	-.25	-.35	-.10	.37	.080	-.20	.26	.33	.053	-.30	-.21	**.52***	-.33	.14	.12
3. Verb Accuracy (Sent.)				**-.52***	-.36	-.27	-.22	-.23	-.30	.33	-.35	-.38	**-.54***	-.081	.033	.006	-.22	-.015	-.27
4.% Dysfluencies (SP$^{\#}$)					**.59***	.17	.25	**.71****	.35	**-.52***	.44	**.54***	**.52***	.13	.15	.10	-.027	.050	.34
5.% Dysfluencies (SG†)						-.068	.17	.21	.27	-.28	.39	.46	.44	.41	.21	-.30	-.44	**-.56***	.086
6. Pause Length (SP$^{\#}$)							.22	.024	.000	.003	-.16	-.22	.17	-.024	.11	-.079	**.53***	.31	.10
7. Pause Length (SG†)								.38	.42	-.12	.018	.029	**.59***	.37	.43	-.30	-.13	-.29	.081
8. Utterance Length (SP$^{\#}$)									.47	-.50	.44	**.64****	**.59***	.000	.23	.28	-.14	.097	.38
9. Utterance Length (SG†)										-.001	.12	**.51***	**.77*****	.25	.025	.085	-.38	-.33	-.12
10. Lexical Density (SP$^{\#}$)											**-.60***	-.32	-.34	.35	.26	-.22	.24	-.012	**-.54***
11. Lexical Density (SG†)												**.57***	.39	-.060	-.44	.35	-.23	.20	-.060
12. RT (SP$^{\#}$)													**.62***	.14	-.038	.30	-.25	-.12	.28
13. RT (SG†)														.20	.009	.15	-.24	-.33	.095
14. Set Shifting															.39	**-.62***	-.31	-.44	-.16
15. Inhibition																-.35	.080	-.30	.34
16. Updating																	.28	.47	.027
17. Short Term Memory																		**.70****	.044
18. Working Memory																			-.12
19. Processing Speed																			

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Underscored values are significant with Benjamini-Hochberg correction applied (Note: in the PD group, no relationships remained significant after the correction was applied)

$^{\#}$ Measures from sentences produced in the Sentence Production (SP) task (in response to picture stimuli)

† Measures from sentences produced in the One Word Sentence Generation (SG) task (in response to a given verb)

Table 38.

Relationship between word production accuracy, sentence constructions measures and cognitive abilities in the Control group

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Noun Accuracy		.047	-.016	-.19	-.21	**-.42***	.28	.063	.26	.035	.052	-.31	.071	-.068	-.076	**.48***	.26	.022	-.31
2. Verb Accuracy			.29	-.32	-.19	-.31	.19	-.34	-.066	.31	.072	.12	.25	-.001	.21	.19	.090	.062	.068
3. Verb Accuracy (Sent.)				-.39	-.031	**-.43***	.22	**-.49***	-.30	.39	.16	-.079	-.17	-.089	-.056	.073	.19	.10	-.12
4.% Dysfluencies (SP$^{\#}$)					**.54****	**.47***	.081	**.68*****	.33	**-.71*****	.072	**.60****	**.43***	-.25	.19	-.15	-.13	-.16	-.18
5.% Dysfluencies (SG†)						.15	.28	.15	-.007	-.29	**.50***	.20	**.44***	-.045	**.42***	-.28	.031	-.29	-.26
6. Pause Length (SP$^{\#}$)							-.11	.23	-.058	-.14	-.12	.31	.36	-.083	.072	**-.51****	**-.49***	-.16	.064
7. Pause Length (SG†)								-.021	-.23	.085	.39	.11	**.46***	-.20	.30	-.073	.045	-.30	-.17
8. Utterance Length (SP$^{\#}$)									.31	**-.82*****	-.029	**.61****	.33	-.12	-.093	.20	-.083	-.063	-.10
9. Utterance Length (SG†)										-.33	-.37	.23	-.062	-.17	-.28	.38	.32	.22	-.15
10. Lexical Density (SP$^{\#}$)											.005	**-.46***	-.16	.17	-.17	-.11	.006	.11	.10
11. Lexical Density (SG†)												-.083	.29	.036	.14	-.12	-.024	-.38	-.076
12. RT (SP$^{\#}$)													**.61****	-.037	.070	.074	-.32	-.27	-.044
13. RT (SG†)														-.075	**.41***	-.21	-.37	**-.57****	-.15
14. Set Shifting															-.046	-.011	-.20	-.29	-.069
15. Inhibition																-.39	-.20	-.27	.092
16. Updating																	.36	.29	**-.55****
17. Short Term Memory																		**.68*****	-.37
18. Working Memory																			-.16
19. Processing Speed																			

*p < .05, **p < .01, ***p < .001

Underscored values are significant with Benjamini-Hochberg correction applied

$^{\#}$ Measures from sentences produced in the Sentence Production (SP) task (in response to picture stimuli)

† Measures from sentences produced in the One Word Sentence Generation (SG) task (in response to a given verb)

7.3.1.1 Noun and Verb Production

Noun Production

In the PD group, no significant correlations were evident between noun production and performance in any cognitive domain. In the control group, a significant moderate, positive, relationship between performance in the noun naming task and the updating task (r_s = .48, p =.015) was evident.

Verb Production

No significant correlation between performance in any cognitive task and verb naming accuracy at a single word level was evident in the control group. In the PD group however, a significant, moderate positive relationship between updating ability and single word, verb naming ability was evident (r_s = .52, p =.038).

When considering verb production in a sentence context, no significant correlations between scores in any of the cognitive tasks and verb production accuracy were evident in either group.

7.3.1.2 Sentence Construction

7.3.1.2.1 Fluency

No significant correlations, in either group, were evident between scores in any of the cognitive tasks and the percentage of dysfluencies per utterance in the sentence production task (i.e., sentences produced in response to a picture). In contrast, significant relationships were evident between average pause length in the sentence production task and cognitive performance, in both the PD and control group. In the PD group, a positive relationship between pause length and short term memory capacity emerged (r_s = .53, p =.033) such that, as short term memory capacity increased, so did average pause length. A significant relationship existed between these same elements in the control group (r_s = -.49, p =.013), however presented in the opposite direction. Further, in the control group a significant, negative correlation was evident between average pause length and updating (r_s = -.51, p =.009), suggesting that, as updating scores increased, average pause length decreased.

Somewhat the reverse pattern emerged when considering data from the one word sentence generation task (i.e., sentences produced in response to a given verb). Whilst in neither group did any significant relationship between average pause length and performance within any cognitive domain emerge, a significant, moderate correlation between the percentage of dysfluencies evident and cognitive performance presented in both groups. There was divergence between the groups however in the ability between which the relationship existed. In the PD group, this relationship was between working memory and the percentage of dysfluencies (r_s = -.56, p =.024) suggesting that, as scores in the digit span backwards task increased, the percentage of dysfluencies decreased. In the control group, the relationship was with inhibitory control (r = .42, p =.041) with the average percentage of dysfluencies evident within sentences shown to increase as inhibitory cost scores increased.

7.3.1.2.2 Lexical Content

No significant relationships between utterance length – either in sentences produced in response to a picture, or a given word – and any cognitive ability were present. This same pattern was evident in both groups. When considering lexical density, a relationship did emerge; confined to sentences produced in the sentence production task (i.e., in response to a picture), in the PD group. Specifically, a moderate, negative relationship between processing speed and lexical density (r_s = -.54, p = .031) was evident.

7.3.1.2.3 Response Time

A significant relationship emerged between performance within two cognitive domains and RT in the one word sentence generation task (i.e., sentences produced in response to a given word). These relationships were confined to the control group. Specifically, there was a moderate, positive correlation between RT and inhibition (r_s = .41, p = .049) and a moderate, negative correlation between RT and working memory performance (r_s = -.57, p = .003).

7.3.1.3 Other relationships of interest

Whilst of primary interest within the correlation analyses conducted was the relationship between the language and cognitive variables of interest, other patterns potentially worthy of note – particularly where these patterns varied between individuals with PD and controls – will be touched upon here.

Noun and Verb Production

A strong, positive relationship between noun and verb production accuracy was seen in the PD group (r_s = .71, p = .002). No significant association between noun and verb production accuracy was seen in the control group.

Fluency

Interesting differences in the pattern of relationships concerning average pause length in the sentence production task (i.e., sentences produced in response to a picture) presented between the PD and control groups. In the PD group, no significant relationship between average pause length and any other language variable was evident. In contrast, in the control group, average pause length showed a negative, moderate correlation with verb production accuracy in a sentence context (r_s = -.43, p = .034), and a moderate, positive correlation with the percentage of dysfluencies within the sentence produced (r_s = .47, p = .018). Again looking at sentences produced in the sentence production task, a moderate, negative correlation (r_s = -.52, p = .041) was seen in the PD group between verb production accuracy in a sentence context and the percentage of dysfluencies evident within the sentence produced. No such relationship was evident in the control group.

Lexical Content and RT

Staying for a moment with verb production accuracy in a sentence context, a moderate, negative correlation (r_s = -.49, p = .014) between this measure and the length of sentences produced in response to picture stimuli was seen in the control but not the PD group. Conversely, a moderate, negative correlation (r_s = -.54, p = .030) was highlighted between verb production accuracy in a sentence context and the time taken to produce sentences in response to a given verb (i.e., in the one word sentence generation task) in the PD group. Interesting to observe, too, was the moderate-strong, negative correlation (r_s = -.60, p = .015) that emerged in the PD group between lexical density in sentences produced in response to a picture (sentence production task) and those produced in response to a given verb. A significant, moderate-strong correlation was found to exist in the PD group, too, between the time taken to produce sentences in response to a given verb and the length of sentences both produced in response to that given verb (r_s = .77, p < .001) and in response to a picture (r_s = .59, p = .017).

Benjamini-Hochberg Correction

Whilst this analysis was exploratory in nature, Benjamini-Hochberg correction was additionally run in an effort to extract which of any indicated relationships may be the most pertinent to explore further within future studies. No significant correlations survived correction in the PD group, whilst seven did so in the control group. None of those which remained following correction in the control group were between language and cognitive variables. The majority were between two language variables (specifically – all in sentences produced in response to a picture – between the percentage of dysfluencies and utterance length [$r_s = .68$, $p < .001$], the percentage of dysfluencies and lexical density [$r_s = -.71$, $p < .001$], the percentage of dysfluencies and RT [$r_s = .60$, $p = .001$], lexical density and utterance length [$r_s = -.82$, $p < .001$], utterance length and RT [$r_s = .61$, $p = .001$] and RT in the sentence production and RT in the sentence generation task [$r_s = .61$, $p = .002$]), with one between two cognitive variables also surviving (specifically, that between short term memory capacity and working memory, $r_s = .68$, $p < .001$).

7.4 Discussion

The aim of this analysis was to explore whether any relationships existed between the specific cognitive abilities examined and language performance in individuals with PD. Correlational analysis was run on data collected from both PD and control participants, allowing for any differences in the evident relationships between groups to be examined. Additionally, whether any relationships existed between performance in the different language tasks was investigated. The results are discussed in three parts: the first concerned with verb and noun production performance and cognitive abilities, the second concerned with measures of sentence construction and cognitive abilities and the last concerned with any significant relationships evident between performance in the language tasks.

Before commencing that discussion, attention will first be paid to the correlations which survived corrections for multiple comparisons.

7.4.1 Benjamini-Hochberg Correction

What was perhaps most interesting to observe was that none of the correlations which survived correction had been selected for reporting and particular discussion by the author, due to the fact that the patterns seen were common between the groups and largely similar in magnitude. In over half of the relationships which survived correction in the control group, the correlation coefficient for that same relationship was actually slightly greater in magnitude in the PD group, despite not remaining significant following correction. It seems possible that reduced statistical power in the PD group may have fed into this and, and such, seeing the correlations as qualitatively different due to their survival (or not) following correction would likely be misguided.

Nonetheless, the correlations which did survive present some interesting points to consider. Firstly, whilst it is perhaps not surprising that strong, significant correlations were evident amongst the sentence construction measures under investigation, those which survived correction all involved measures from the sentence production task. This may be relevant to explore further to understand the degree to which the association between linguistic variables correlate in different tasks. In turn, this could be useful in shaping appropriate analyses for future studies (see, for example, discussion by Huberty & Morris, 1989, regarding when it is appropriate to employ multivariate analysis as compared with multiple univariate analyses), depending on task. Secondly, it is noticeable that none of the correlations between pause length and other sentence construction measures survived correction. Again, exploring this further could provide useful information regarding what mechanisms are underpinning particular linguistic factors – including in typical individuals – and again, from knowledge of correlation between variables, provide useful information regarding the most appropriate analysis to conduct when considering multiple linguistic variables.

7.4.2 Noun and Verb Production

A relationship between updating ability and single word retrieval accuracy was seen in both individuals with PD and controls. The grammatical class of the single word in question, however, varied between groups. Whilst in the PD group a relationship between updating and verb naming accuracy was seen, in the control group the relationship was between updating and noun naming accuracy. In both instances, word retrieval accuracy was shown to increase as updating performance increased.

Upon first consideration, these findings appear to directly contradict those reported by Bocanegra et al. (2015). In contrast to this study, Bocanegra et al. (2015) observed the same pattern of cognitive predictors in PD and controls with, in both groups, performance in the executive functioning measure utilised found to predict performance in object semantics but not in action semantics or verb naming. Where this study and that conducted by Bocanegra et al. (2015) clearly diverge however is in the measure of executive functioning used. Within Bocanegra et al.'s study, executive functioning was assessed using a test battery (the INECO Frontal Screening Battery; Torralva et al., 2009, as cited in Bocanegra et al., 2015, p. 240) which collapses performance across individual executive functions and does not appear to include a specific measure of working memory updating ability. Thus, the potential remains that, whilst when looked at 'en masse' using a screening tool, executive functioning performance does not predict verb naming ability, when performance within each of the separable executive functions is considered, a different pattern emerges. The question nonetheless remains as to why, in the control group, updating ability appeared to be associated with noun naming ability whilst, in the PD group, the same ability was linked to verb naming.

It could be the case that any potential contribution of updating ability to word production in PD is somewhat extraneous; such that an association between the two processes only appears in the presence of an already degraded conceptual system – in other words, it is a compensatory measure relied more heavily upon when, due to the degradation of motor representations in PD (see Section 1.2.3.2 for discussion), processing cannot proceed as would typically be expected. Such an explanation seems plausible but does not offer any insight as to why the reverse pattern (i.e., that a correlation was seen between noun but not verb naming) was evident in the control group. If updating ability is potentially contributing significantly to noun naming ability in control participants, why does it not also appear to be doing so in individuals with PD? It was not the case that noun naming accuracy scores were significantly different between the groups, which could suggest that the *lack* of an association between updating and noun naming was deleterious. And, by extension, suggest that the lack of any such association in the PD group was the effect of pathological alteration, resulting in an alteration from ‘typical’ processing.

As previously mentioned, an association between object semantics and executive functioning in control participants has been reported elsewhere (Bocanegra et al., 2015) but not in the absence of the same association being evident in individuals with PD (Bocanegra et al., 2015). One potential hypothesis to account for the findings seen here is that the exact cognitive processes which are associated with word production – whilst both tracing back to the same *n*-back task – differ between individuals with PD and controls. The task employed was designed to tap as precisely into updating ability as possible, however it is acknowledged that performance within the *n*-back task has been linked to binding and the ability to manage interference, as well us updating ability (Chatham et al., 2011). The possibility arises therefore that the pattern observed represents different patterns of underlying cognitive alteration or reliance between individuals with PD and controls. Which, if it were to be assumed that these different cognitive processes were differentially associated with noun and verb naming – could explain the differing patterns of association seen between groups.

The conclusions which can be drawn from this analysis are limited, however do provide a basis from which further exploration could be conducted. Unpicking – perhaps through adopting a latent variable approach – whether the differing relationships between performance in the *n*-back task and single word language tasks seen between individuals with PD and controls reflects different underlying cognitive processes could help elucidate the patterns seen within this study. It might be interesting, too, to explore how the association between performance within the *n*-back task and word production shown here may play out in natural language situations. One could hypothesise that, within the single word naming tasks, altered ability to update working memory may result in information from the previous stimulus disrupting the current one (potentially further compounded by reduced ability to supress irrelevant meanings in PD; e.g., Copland et al., 2009). Whether this effect would be evident within natural conversation, at the level of word retrieval – or whether its presence may be more noticeable as an effect on language use (pragmatics), through, for example, an altered ability to update in response to moving discourse topics – might additionally be interesting to explore.

7.4.3 Sentence Construction

Fluency

The relationships evident between cognitive ability and sentence fluency – as measured through the percentage of dysfluencies – varied according to stimulus type. There was not, in either individuals with PD or controls, any indication of a significant relationship between the percentage of dysfluencies evident in sentences produced in response to a picture and any of the core cognitive abilities investigated. In contrast, there was evidence of such a relationship when considering the sentences produced in the one word sentence generation task (i.e., in response to a given verb); the pattern of which varied between groups.

In the PD group, the percentage of dysfluencies evident was found to decrease as working memory ability (as measured through performance within the backwards digit span task) increased; a pattern that was not seen in the control group. There is – as discussed in Section 3.3.6.4 – some ambiguity as to what backwards digit span is actually a measure of, with some purporting performance to reflect visuo-spatial recourses, as opposed to working memory manipulation per se (St Clair-Thompson & Allen, 2013). Potentially, either or both could be factoring into the percentage of dysfluencies observed. In contrast to the condition within which a picture is provided, no context was provided in the one word sentence generation task. Thus, it was up to the individual to access meaning of the word, the context within which it could allowably be used and create a sentence accordingly. This may have required visuo-spatial ability – if we are to assume that individuals may have visualised the scenario which was forming the sentence being created. Equally, such a process may have placed demands on working memory capacity, through the requirement both to store information and consider the various sentence options which could be chosen (see Logie, 2011 for theoretical disucssion regarding the organisation of working memory).

Either way, it is interesting that this ability may be contributing to sentence generation in the PD group, whilst not doing so for controls. This could, tentatively, suggest that the processes employed to complete the one word sentence generation task varied between groups, with individuals with PD showing a greater reliance on visuo-spatial processing and/or working memory manipulation. Furthermore, the fact that inhibitory control was shown to be associated with the percentage of dysfluencies evident in sentences produced by the control group, but not in individuals with PD, would suggest that the reliance on and/or compensatory recruitment of visuo-spatial processing and/or working manipulation ability in PD may override the role of other contributing cognitive functions. This, in itself, is interesting to think about, given the proposed role of inhibition in controlled semantic retrieval, and the fact that the employment of such executive control may be impaired in PD (as per the findings of Crescentini, Mondolo, et al., 2008, for example). Whilst these analyses were exploratory, the pattern of associations seen offer potential directions for future research.

In contrast to the findings from the analysis concerned with the percentage of dysfluencies evident, broadly the opposite pattern was seen when considering average pause length. Here, associations between cognitive performance and average pause length were seen in sentences produced in response to a picture (i.e., in the sentence production task), but not in response to a given verb. Interestingly, a relationship between average pause length and short term memory capacity was observed in both individuals with PD and controls. However, the direction of this relationship was opposed with, in the PD group, better performance in the forwards digit span task actually found to be associated with increased pause length. This could, in a sense, support the idea that the presence of increased pause lengths in the PD group was a compensatory measure – in that, the presence of increased pause lengths was associated with the recruitment of intact cognitive resources, which may in turn have supported successful sentence construction. The fact that this pattern is the opposite to that seen in the control group – where decreased performance within the digit span forwards test was associated with the presence of increased pause lengths – could in turn potentially point to PD pathology leading to a fundamental shift in the contribution of cognitive processes to language production. It should be stressed that these ideas are purely hypothetical, however could form the basis for further investigations.

Additionally important to consider is the finding that, whilst updating ability was found to be negatively associated with pause length in the control group, no such association was seen in the PD group. This could potentially add weight to the idea that increased pause lengths are occurring for different underlying reasons in individuals with PD as compared with controls. And that their function, too, may be opposing – effectively supporting language production in PD, but reflecting a decline in cognitive performance in controls. Again, this idea is purely speculative, and many other reasons may explain this pattern of performance. Further, the limited conclusions that can be drawn from this analysis must be acknowledged. Nonetheless, the pattern seen here sparks some interesting thoughts, which may be worth exploring further.

Lexical Content

No significant relationship between utterance length and any cognitive ability was evident, in either group. This finding appears to stand in some contrast to that reported by Murray (2000) who, albeit using different tasks, saw a relationship between short term memory and MLU in their group of individuals with PD. This difference could potentially reflect differences in the general cognitive functioning of the two groups of individuals with PD (two individuals in Murray's [2000] study received scores suggestive of mild dementia on the measure of general cognitive ability employed) and/or differences in the cognitive and language tasks employed. Importantly, the language task employed by Murray (2000) was a discourse task, necessitating the maintenance of a topic across a series of sentences, which was not required within the task employed within this study. It could be expected that this would place greater demands on short-term memory capacity, potentially creating a trade-off between topic maintenance and MLU not seen in this study.

In contrast, an association was seen in the PD group between processing speed ability and the lexical density of sentences produced in response to a picture stimulus. Specifically, greater lexical density was associated with faster processing speed. Given that the processing speed task utilised assessed visual processing time, this may reflect the advantage provided through faster processing of the visual stimuli. That being said, the provision of additional information – which could reflect deeper processing of the stimuli – resulting in increased lexical content would not necessarily fit the expected pattern. If it is assumed that more efficient visual processing translated to the inclusion of a greater amount of optional, additional information, a reduction in lexical content might actually be expected, due to the increased presence of prepositional phrases.

An alternative possibility is that the association reflects presence of a general cognitive slowing in the PD group; such that, whilst the effect of the time constraint built into the tasks (through asking individuals to provide their sentences as soon as they could, once they had been thought of) was not sufficient to place any noticeable processing demands in the control group, it did in the PD group – resulting in the association seen. The difference in association patterns between individuals with PD and controls may, equally, represent differences in sentence planning and formulation time. If the time period across which the process of sentence formulation took place was even slightly lengthened in the PD group (it is assumed that any potential difference must be slight, given that there was no significant difference in RT between groups, in either sentence construction task – see Section 5.4.3), this could again increase processing demands in the PD group to the degree that an association between processing speed and lexical content emerges, when it is not seen in the control group. Once again, these ideas are speculative however the association observed here may provide useful avenues for exploration in future studies.

Response Time

A relationship between RT in the sentence generation task (i.e., the production of sentences in response to a given verb) and two cognitive abilities – inhibition and working memory – emerged in the control group. Specifically, it was indicated that as inhibitory cost scores increased, RT increased whilst when working memory ability increased, RT decreased. In this one word sentence generation task, no context was provided which, it was hypothesised, would result in increased choice at both a conceptual and lexical level. This, in turn, was expected to create greater executive control demands (specifically, the need to inhibit competing alternatives; see Crescentini, Mondolo, et al., 2008) as well as placing greater demands on working memory capacity. Thus, the fact that a relationship between inhibitory control, and working memory ability, and RT in the sentence generation task appears to be in line with the demands of the sentence generation task. What is particularly interesting to consider however is why the same relationship between these variables was not seen in the PD group.

Could this potentially indicate differences in the depth of processing between the groups? It could possibly be the case that, in the PD group – perhaps as a result of delayed semantic activation (e.g. Angwin et al., 2007) – not as many options were activated, meaning that the increased inhibitory control and working memory demands indicated in the control group were not required in the PD group, leading to the differences seen. Such a question cannot be answered here but could potentially be addressed in future research using a paradigm within which the time individuals are given to produce a sentence is manipulated. What this finding does highlight however is the value of looking at correlations between cognitive and language performance in control as well as PD participants, allowing for the identification of relationships that *are not* evident in the PD group (as compared with controls), as well as those which are.

7.4.4 Other Relationships of Interest

Discussed within this final section are observations regarding relationships of particular interest evident between performance in the various language tasks, in each group.

Noun and Verb Production

It was interesting to observe that, in the PD group, a strong positive relationship between noun and verb naming accuracy emerged; a relationship which was not evident in the control group. The fact that this relationship emerged could be taken to suggest that the processes underpinning accuracy in noun and verb naming in the PD group were the same and, in turn, potentially point away from the semantic hypothesis (in that, if verb processing is differentially impaired in PD as a result of degraded motor representations whilst noun [object] naming is spared, a relationship between performance in the two would not be expected). That being said, it could also be argued that, because the nouns utilised within the task varied in the degree of action associated with them, that in at least some instances, their successful retrieval may also have relied upon motor networks. Therefore, the correlation between the two could indicate the shared requirement of motor representations for successful retrieval of some items across both tasks. If that were the case however, the same pattern of association would be expected in the control group, which was not the case.

One possibility is that the difference in the relationship evident between noun and verb naming accuracy between the groups represents differences in the types of errors made and, more particularly, the consistency of them. Let us say (hypothetically) that, in the PD group, errors across the board tended to always be of the same type (e.g., visual), whilst errors in the control group showed a greater degree of variation (e.g., were sometimes of a visual nature, sometimes of a semantic nature) – both between the verb and noun naming tasks, and between individual control participants themselves. If that were the case, one might only expect to see an association between noun and verb accuracy in the PD group because, in contrast to the control group, performance in both tasks reflected the same pattern of errors. Errors were not categorised according to nature in this study, however analysing whether any difference in the pattern of errors made between individuals with PD and controls in future studies would enable further exploration of the points considered here.

Sentence Construction Measures

Bearing in mind the discussion in previous experimental chapters regarding the increased average pause length observed in the PD group, it is worth considering the patterns of association that emerged between average pause length in the sentence production task (i.e., sentences produced in response to a picture stimulus) and other language measures. In the control group, both verb production accuracy in a sentence context and the overall percentage of dysfluencies evident were shown to be associated with pause length, such that average pause length increased in line with the percentage of dysfluencies and decreased as verb 'correctness' increased. No such relationship was evident in the PD group however, suggesting that the factors which may be contributing to increased pause length are varying between the two groups. This pattern in many respects fits with the differing pattern of association between short term memory ability and pause length presented earlier in this section. In contrast to controls, for whom increased pause length would appear to be associated with reduced cognitive (i.e., short term memory) and linguistic (i.e., verb correctness) performance, in the PD group pause length was not influenced by verb correctness and actually associated with better short term memory performance – potentially reflecting a strategic measure to allow sentence construction to proceed in an otherwise equivalent manner to controls.

There is also the possibility that the difference in the relationship between verb 'correctness' and pause length between the two groups indicates a difference in each group's awareness of whether the verb at the centre of the sentence was correct or not – and, somewhat by extension, their awareness of the number of possible verbs which could be used to describe the action taking place in the picture, and the consequent degree of likelihood that their answer would be correct. This, further, could be hypothesised to reflect a difference in the speed and depth of semantic processing between groups (see Angwin et al., 2007, for example) – or, potentially, a difference in visual processing and the integration of elements shown within the picture.

This argument is complicated however by the indication of an association in the PD group between verb correctness (in a sentence context) and the percentage of dysfluencies within the sentences produced and, conversely an association between verb correctness in the control group and the length of utterances produced. Further, and again not seen in the control group, an association was also seen in the PD group between verb production accuracy in a sentence context and the time taken to provide sentences from a given verb (such that, as verb production accuracy in a sentence context increased, the time taken to provide a sentence in response to a given verb decreased). What appears to be emerging therefore is an interesting and complex pattern of associations between verb correctness within a sentence context and sentence construction measures, which varies between individuals with PD and controls. What might be underpinning this variation would be interesting to explore further in future studies.

Summary

The pattern of associations seen between the language measures and cognitive abilities, and between the language measures themselves, was found to vary between individuals with PD and controls. Various potential reasons for these differing patterns have been proposed, each of which could form the basis for further investigation within future studies. Whilst the conclusions which can be drawn from the correlational analysis conducted are limited – and it should be reiterated that the relationships which formed the bulk of this discussion did not survive correction for multiple comparisons therefore extreme caution is warranted – what the findings from this analysis clearly emphasise is the importance of looking at the relationship between the variables of interest in both individuals with PD and controls, allowing any difference in the pattern of associations between the two groups to be identified.

8 General Discussion

The aim of this research was essentially twofold: 1) to extend current understanding of verb processing in PD and how this might be impaired; and 2) by looking at the influence of a verb's characteristics on sentence construction (particularly in relation to fluency and lexical content), to bring together two strands of the literature which, until this point, have remained largely separate. Of additional interest was how task affected language performance within the same group of participants, an investigation which, again, had not previously been conducted. Finally, another important, novel aspect of the current work was to explore the relationships amongst specific cognitive and language functions, aimed at highlighting cognitive mechanisms that might underlie language difficulties in PD.

Presented here is a general discussion of the findings previously considered in depth within each individual chapter. The discussion is presented in two parts: the first concerned with verb and noun processing and the second with sentence construction. This leads into a detailed consideration of the study's limitations and, in turn, how these limitations may be addressed in future research. Also included within this section are ideas for future exploration, arising from this study. This section closes with a final conclusion, summing up the findings from this thesis and what it achieved.

8.1 Verb and Noun Processing in PD

In contrast to previous reports (e.g., Bocanegra et al., 2017; Cotelli et al., 2007; Rodríguez-Ferreiro et al., 2009) findings from this study do not support the presence of a specific verb naming deficit in PD. That is *not* to suggest that verb processing is uniformly unimpaired in PD: rather that, in this group of individuals with PD – with a cognitive profile comparative to that of controls and with a relatively low disease duration – under the conditions examined here, no deficit in verb processing emerged. Whilst not of primary consideration within this study, the profile of the PD group included within this study is interesting to consider in relation to the work concerned with identifying trajectories of cognitive decline in PD (Reid et al., 2011; Williams-Gray et al., 2007). Specifically, this group of individuals with an average disease duration of 6.98 years, showed no impairment in any of the measures of executive functioning conducted and showed comparable linguistic and general cognitive performance as controls. Future studies concerned with identifying prognostic markers may benefit from considering more specifically what is underlying the apparent semantic/linguistic alteration seen and whether, for example, there is any difference in the pattern of cognitive decline in PD according to whether any verb processing impairment observed appears to be sui generis or reflective of altered executive control.

The pattern which emerged across both groups – i.e., that nouns have a processing advantage as compared with verbs – is exactly as might have been expected, given previous findings (Mätzig et al., 2009). The fact this difference reached significance in the control group however was a surprise and might point the fact that, when the processing demands placed are great enough (demonstrable within this study through the increased difficulty of the verb naming stimuli) a significant difference in performance according to word type can appear in control participants, too. Establishing in future studies under what conditions a difference in verb and noun naming performance appears in PD beyond typical performance could help elucidate the root of any such impairment. Here, stimuli were constrained by both action content and grammatical complexity. Whether the pattern seen might be different if, for example, the verbs to be named were all high motion and/or upper limb actions (see Bocanegra et al., 2017 and Roberts et al., 2017, respectively) and matched according to the number of conceptual options, would be interesting to see.

Against predictions, the verb naming accuracy of individuals with PD was not differentially influenced by either the action associated with the verb or its grammatical complexity, in either a single word or sentence context. Another unexpected finding to emerge was that – across all participants – action and transitivity were found to have a significant and interacting effect on verb naming accuracy. Consideration of these findings (see Section 4.4.1) presented a number of potential confounds: perhaps most notable of which was the semantic connectedness and number of conceptual options associated with the verb. Acknowledged, too, was the fact that the verbs utilised may not have been 'high action' enough for an effect of motor content to be seen, given the suggested specificity of the *sui generis* verb impairment in PD (e.g. Bocanegra et al., 2017; Roberts et al., 2017). These findings highlight the complexity which emerges – to some degree as the result of some elements of the verb being tightly controlled, but not others – when assessing lexical-semantic processing in PD, and the need for these potential confounds to be considered in future studies.

Correlational analysis evidenced the presence of a significant moderate relationship between single word accuracy and cognitive ability in both groups. Whilst in both instances the cognitive ability in question was working memory updating, in the control group the link seen was with noun naming, whilst in the PD group it was with verb naming. The exact reason for the opposing pattern is unclear, however could potentially reflect differences between the two groups in terms of what is influencing performance within the *n*-back task employed (i.e., is it updating ability itself, or a reflection of other cognitive processes required for successful completion of the task?).

8.2 Sentence Construction in PD

The main take-away finding from this study regarding sentence construction in PD is that, when the verb naming ability of individuals with PD is not diminished, sentence construction – eliciting/utilising the same verbs as at a single word level – is similarly unimpaired. Across the board, the pattern of performance in the PD group was comparable to that of controls, with one notable exception: average pause length in sentences produced in response to picture stimuli. Pause length in PD was not however shown to be influenced by the nature of verb at the centre of the sentence, nor by whether verb retrieval, regardless of its characteristics, was required (as measured through comparing performance in the sentence production and one word, sentence generation tasks). Interesting to observe, too, was the differences in the relationships between pause length and other cognitive and language variables between the PD and control groups. The findings would indicate that the root cause of increased pause lengths differed between individuals with PD and controls, with increased pauses potentially representing a compensatory measure in the PD group, allowing sentence construction to proceed otherwise comparably as compared with controls.

The finding that average pause length is increased in PD is in line with a number of findings previously reported (e.g., Alvar et al., 2019) and – most importantly – has been indicated to have the potential to influence communicative success at a discourse level. Whilst not considered here, within the work previously mentioned (Alvar et al., 2019), of interest was the way in which these pauses were marked, and the functional impact this may have within discourse, particularly. Understanding more about what is underpinning the increased pause lengths observed – and, in turn, under what conditions and constraints these pauses are likely to present – could be an important direction for future research (see Alvar et al., 2019 for related discussion regarding pause marking in particular).

It should be stressed too that, whilst the findings here do indeed suggest that, when verb naming ability is unimpaired in PD, sentence construction is (largely) equally unimpaired, cognitive ability was also found to be preserved in this group of individuals with PD. Thus, it could as equally be argued that the preserved sentence construction seen here is a consequence of preserved cognitive ability. The pattern of relationships between cognitive performance and sentence construction varied slightly between individuals with PD and controls. This picture was complex, however – it was not simply the case that cognitive processes appeared to be relied upon more heavily during language processing in the PD group. This is important to bear in mind in future studies. If the relationship between language and broader, supporting cognitive processes is to be understood in PD, it is vital that understanding of the role within typical functioning is also expounded. Further, gaining a better understanding, through application of a longitudinal design, of how language processing may alter depending on PD subtype, according to the cognitive profile of individuals at baseline (see Kehagia et al., 2013), could be of both theoretical and practical utility.

8.3 Limitations, Implication of Findings and Conclusions

8.3.1 Limitations and considerations for future research

The research, whilst carefully planned, is not without its limitations. These limitations are discussed below with, where applicable, suggestions for how these might be addressed in future work.

It must be acknowledged that the size of the sample recruited was modest, which could have affected findings through reduced statistical power. The number of participants involved in the study may have been influenced by the time commitment required. Whilst running three sessions allowed for the collection of a significant amount of data, it may also have prevented some individuals coming forward to be involved in the study, thus impacting upon the size of the sample. All that being said, sample sizes (PD group: n = 16; Control group: n = 25) were comparable to previous studies of a similar type (e.g., Bocanegra et al., 2017; Troche & Altmann, 2012) and sample size appropriately borne in mind when interpreting the results.

It should further be acknowledged that, due to the constraints placed, the number of tokens within each level of the factors under investigation were small; particularly within analyses within which both a verb's action and transitivity was under consideration. This constraint arose partly through the strict linguistic rules applied but was further exacerbated by the use of picture stimuli. This is a trade-off which may wish to be considered within future studies. Whilst the use of picture stimuli here allowed both for the comparison of performance in different linguistic situations and for the direct comparison with previous studies from which the research questions investigated within this study emerged, future studies within which the linguistic variable of interest is divided along multiple lines may wish to adopt an alternative design, which does not rely on the translation of the target into a visual representation.

Further, for the reasons just outlined – i.e., their indicated sensitivity and direct comparability with previous paradigms from which the questions investigated within this study had been raised – single task condition picture-based production tasks were focussed on within this study. The inclusion of dual task paradigms – particularly in this group of individuals with PD whose cognitive performance was comparable to controls – could have provided useful information regarding the conditions under which altered language processing might present (i.e., as specific cognitive demands increase) and are certainly worthy of consideration within future studies. Additionally, the development and employment of priming tasks (such as that employed by Angwin et al., 2007) with verb characteristic as the independent variable(s) could prove fruitful. The inclusion and comparison of performance within both on- and off-line tasks within future studies could also help separate central effects of language processing from those of task and, through manipulation, increase understanding of the conditions (in terms of cognitive demand) under which language processing difficulties may present in PD.

In this study, the words utilised were divided according to three characteristics. The first was word class, with targets divided according to whether their predominant position of speech was that of noun or verb. The second was action/motion, applied in the verb category in terms of whether the verbs had a high or low level of action associated with their meaning, and in the noun category according to the level of motion associated with the noun. Finally, the third characteristic, applied only in the verb category, was grammatical complexity, with verbs divided according to the number of arguments they were required to take. These lines of division were carefully formulated, in line with the aims of the research being conducted. However, as acknowledged throughout this thesis – although discussed particularly in Section 3.4.1 – a number of potential cross category variables, which were not controlled for here, became apparent during consideration of the findings and may have been contributing to the findings seen. This, in turn presents questions regarding along which lines it may be most appropriate to divide and categorise words in future studies. And, furthermore, the optimal number of characteristics along which to divide, to minimise the risk of findings inadvertently becoming muddied.

Concern regarding how word classes should be categorised is not a new one, with the semantic confound between the grammatical categories of verb and noun a point of discussion within the current literature (see Section 1.2.3.1). Another factor potentially important to bear in mind however, which has largely been left unconsidered in relation to word categorisation, is the richness of the word's semantic associations (Malyutina & Zelenkova, 2020) and the number of contexts within which it can appear which, by extension, influences the number of conceptual options which are associated with it (Breedin et al., 1998). Depending on the exact question being addressed, it may be appropriate in future studies not to divide the target words under consideration according to position of speech (i.e., verb and noun), but instead according to related conceptual options and measures of semantic meaning. Such an approach would enable direct comparison between words with comparable degrees of semantic richness/conceptual options and, in turn, increase understanding of the factors which influence word retrieval, both in individuals with PD and controls. Further, if lexical-syntactic complexity was also manipulated, the degree to which lexical-syntactic information influences production at a single word level could also be elucidated. If it were, for example, found that verbs were more difficult to retrieve than nouns which had been matched according to semantic content and richness, this could indicate a specific role of grammatical complexity – i.e., that the increased lexical-syntactic demands associated with verbs is negatively affecting retrieval. All that being said, it is fully acknowledged that controlling for all potential confounds is likely to be complicated, and potentially impossible. Either way, what this study has highlighted is the complexities of lexical-semantic retrieval, which may wish to be borne in mind in future studies.

PD is a complex condition, and a noticeable degree of heterogeneity is to be expected. By design, no PD subtyping was employed within this study, as a much larger sample size would be required to allow for that. As discussed at various points throughout this thesis, the lack of subtyping according to various characteristics – including cognitive ability (see Section 5.4.1), disease stage (see Section 6.4.1), the degree and specific nature of motor impairment and the presence/absence of limb apraxia (see Section 4.4.1) – and the inclusion of only one comparison group (see Section 3.4.1 and 5.4.1) create limitations to the conclusions that can be drawn. The inclusion of such measures within future studies (according to the specific objective of that study) would be advantageous. Additionally, this study was conducted at a single time point. Again, given the discussion regarding disease trajectory which arose within this study (as a potential means through which to explain differences in findings between this and previous studies), adopting a longitudinal design in future studies may prove fruitful.

Finally, questions regarding individuals' day to day communication were asked only to individuals with PD and not to either their partners, or to neurotypical controls. The degree to which everyday communication was explored was necessarily limited within this study (due to the sheer volume of tasks and the fact that this information did not directly contribute to the experimental questions under investigation) however this omission – particularly the resulting reliance on self-report information from individuals with PD – limited the depth and consequent utility of the information.

Extending these questions both to partners of individuals with PD (i.e., for their opinion regarding their partner's day to day communication, and any functional difficulties they observe) and control participants (particularly if including both younger and older adults) in future studies, could provide useful information. Additionally, the cognitive battery employed, whilst carefully planned, was limited (in relation to the criteria proposed by Litvan et al. 2011). The two domains absent, memory and visuospatial functioning, were assessed to a degree within the cognitive screen employed, however it is fully acknowledged that the information provided by a screening tool is limited and the inclusion of a fuller measure of visuospatial functioning in particular may have provided useful insight.

8.3.2 Implication of findings

This study set out to the increase theoretical understanding of language alteration in PD, through addressing defined gaps identified within the current literature. As outlined within the preceding paragraphs, the study has increased understanding of language processing in PD, as well as presented avenues for further research. In addition, the findings have some clinical utility through increasing current understanding of language processing in PD.

A finding which may be particularly pertinent is the presence of increased pause length in PD. Importantly, the presence of increased pause length appeared in the absence of any other observable language or cognitive alteration in the PD group and may therefore present even in instances within which no linguistic or cognitive alteration has been indicated through assessment in clinic. Although not looked at in this study, previous work has indicated that these longer pauses are less likely to be marked (i.e., filled in some way) in individuals with PD, which in turn may affect communicative success in a discourse context (through individuals potentially losing their turn, for example; Alvar et al., 2019). Further research is needed, however the findings outlined here would suggest that assessing pause length in individuals with PD – and also how they are marked – may be appropriate, particularly in light of the potential impact on day-to-day communicative functioning.

Findings from this study – both when considered alone, and in the context of previous research – have indicated what appears to be a complex relationship between language processing, cognitive processing and disease trajectory in PD. The correlation analyses conducted within this study were exploratory and it is not suggested that any firm conclusions be drawn from the relationships seen. Nonetheless, consideration of why the linguistic performance of this group of individuals with PD varied from previously reported findings led to consideration of differences between the groups in terms of cognitive profile and disease trajectory, according to age at the time of diagnosis. Whilst there is a clear need for further research, what is (re)highlighted from these findings is the heterogeneity of language and cognitive alteration in PD, and the need to assess such functioning on a case by case basis.

8.3.3 Conclusions and Future Directions

Findings from this study extend current knowledge regarding the influence of the semantic and grammatical characteristics of a verb on production in both individuals with PD and neurotypical control participants. Further, they provide evidence to suggest that, when verb production is unimpaired in PD, measures of sentence construction are, in the main, equally unimpaired. The observed increase in pause length evident in the PD group did not appear attributable to verb retrieval generally or be influenced by the specific characteristics of the verb. Additionally, the correlational analysis conducted would further suggest that the presence of increased pause lengths in PD may be facilitatory in nature, reflecting a compensatory mechanism.

Findings from this study present a number of avenues for further exploration; both in relation to language processing in PD, but also in relation to the patterns seen in neurotypical control participants. This study did not include a control group of younger adults, making it impossible to establish whether the pattern seen in controls was reflective of typical ageing processes, or would be expected in all neurotypical adults. That being said, when looking at the influence of lexical-syntactic information on verb retrieval, the findings appeared to be in contrast with those reported by Malyutina and Zelenkova (2020), whose control group comprised younger adults. Thus, there is some indication that the influence of a verb's lexical-syntactic characteristics on retrieval may vary according to age.

Gaining a better understanding of the impact of typical ageing on verb retrieval and – particularly – what might be underpinning the alteration, could in turn increase understanding of the alteration seen in PD. Research would suggest that executive functioning, in line with other fluid cognitive processes, is vulnerable to age related decline (Harada, Natelson Love, & Triebel, 2013). Whilst it was established that the group of PD participants did not vary from control participants in any of the individual measures of cognitive ability, what is not known is whether the control group showed any age-related decline, as compared with younger adults. Thus, the potential remains that age related altered executive functioning may, in both groups, have contributed to the patterns of language processing seen. Including two control groups within future studies – one age matched to the PD group, and one comprising younger adults – could help unpick some of the questions which emerged within this study and provide further insight into the nature of the underlying cause of any language alteration seen in PD (e.g., where does the pattern seen in PD seem to diverge from that seen in typical ageing, and where does it perhaps appear to be underpinned by the same processes of decline, but to a greater degree/at an accelerated rate?). Such exploration would also increase understanding of language processing in healthy ageing.

As touched upon within the Limitations section, individuals within the PD group were not divided according to disease stage, the degree and specific nature of motor impairment, the presence/absence of limb apraxia or cognitive ability. As identified within Section 5.4.1 particularly, dividing individuals in future studies according to verb processing and cognitive ability – sample size depending – may increase understanding of the relationship between verb processing, cognitive ability (both in specific domains, and general cognitive functioning) and sentence construction in both individuals with PD and neurotypical control participants. Comparing performance between individuals with PD and other neurodegenerative conditions may also be elucidating in this regard. Also worthy of consideration within future studies is the age at which individuals received their diagnosis and more specifically, the relationship between age of diagnosis, disease progression, cognitive performance, and language ability. Further, whilst the relationship between motor progression and verb processing does not appear to be a straightforward one, including both the severity and specific nature of motor impairment, as well as the presence or absence of limb apraxia as variables within future studies may assist in untangling the contribution of motor alteration in PD to altered language processing.

Also identified within the Limitations section was the potential confound of semantic richness/number of semantic associations, which was not controlled for within this study. Detailed consideration of how presence of these potential confounds could be addressed was provided in that previous section and will not be repeated here; however, it is nonetheless worth reiterating that considering the influence of semantic richness in future studies may be elucidating. Relatedly, also worthy of potential consideration within future studies may be the linguistic means through which the target concept is expressed. Within Section 3.4.1, the potential that the influence of the action associated with a word could vary according to the sentence slot it occupies – i.e., if it is acting as the ‘action’ within the sentence – was discussed. In that instance, the discussion was concerned with the action associated with a noun, however there are other means through which this potential effect could be explored. For example, whether there is any difference in the ability of individuals with PD to produce a high action concept in the participial form (when it is technically acting as an adjective) versus the present continuous (when it is acting as a verb) would be interesting to consider. The word form in both instances is identical, however the role within the sentence (i.e., whether it is taking the ‘action’ slot) is different. Within this study, tokens were only marked as correct if they had been used as the main verb within the clause. Manipulating this variable in future studies may, however, shed some interesting light regarding whether the way in which the action is used within a sentence influences individuals’ ability to retrieve it.

In conclusion, findings from this sample of individuals with PD found verb production to be unimpaired, as compared with controls. This is in contrast to many findings within the current literature (e.g., Bocanegra et al., 2017) although is not the first to observe no alteration in verb naming (Signorini & Volpato, 2006). Further, this study showed that, when verb production and cognitive processing is intact in PD, sentence construction is also largely unimpaired. It is not suggested that these findings are taken to indicate that language alteration is absent in the PD symptom profile; rather, that they raise questions as to why no alteration was seen here, when it has been seen elsewhere. It is hoped that the discussion presented throughout this thesis provides some working hypotheses for some of these ‘whys’ and, by extension, may pave the way for further research.

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Appendices

Appendix A. Participant Information Sheet (Control Group)

Participant Information Sheet

University of Strathclyde Humanities & Social Sciences

SCHOOL OF PSYCHOLOGICAL SCIENCES & HEALTH

Language Production in Parkinson's Disease

We invite you to take part in a research study.

- We want to find out more about how Parkinson's Disease might affect the words, sentences and groups of sentences that people use. To do this, we are looking at how people complete different thinking and language tasks
- Whether you would like to join the study is entirely up to you.
- Before you decide, we ask that you read through the information in this sheet, so that you understand what the study is about, and what you would be asked to do.
- Please feel free to speak with family and friends about the study if you wish. If anything is unclear, or you have any questions, please get in touch with us. Our details can be found at the end of this sheet.

Important things you need to know:

- This study will involve two groups of participants – one group of individuals with Parkinson's Disease, and one group of individuals without Parkinson's Disease.
- With your consent, we will write to your GP to let them know that you are taking part in the study.
- This study will be completely separate from any normal healthcare appointments.
- We will ask you to attend up to 3 sessions; these can take place in your home or within the University.
- You are very welcome to have someone you know with you in the sessions, but you don't have to.
- We will audio record the spoken responses you give during the tasks.
- All the information collected from the tasks will be anonymised, using a unique code allocated to you.
- Unfortunately, if any of the following apply to you, you will not be able to join the study:
  - If you have had a stroke
  - If you have been diagnosed with another neurological condition
  - If you have a diagnosis of dementia
  - If you have a diagnosis of depression
  - If you have a speech and/or language impairment
  - If you have vision or hearing impairment (that isn't fully corrected through the use of glasses or a hearing aid)
  - If you are younger than 50 years of age
  - If you live outside of Scotland
  - If you are not a native speaker of English

The place of useful learning

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Participant Information Sheet Control Version 3.0 28th November 2016

SCHOOL OF PSYCHOLOGICAL SCIENCES & HEALTH

What is this study about?

The aim of this study is to find out more about how Parkinson's Disease might affect the words, sentences and groups of sentences that people say. Being able to talk with other people is a huge part of everyday life. We want to know more about why language changes may happen in Parkinson's Disease, so that we can better understand how to support individuals with such difficulties.

Who is carrying out the research?

The research is being carried out by Rebecca Wagstaff, a PhD student at the University of Strathclyde. Rebecca has a degree in Speech and Language Therapy and a Master's Degree in the Psychology of Language, and is being supervised by three staff members from the University of Strathclyde: Professor Anja Lowit (Speech and Language Therapy), Dr Louise Brown (Psychology) and Dr Anja Kuschmann (Speech and Language Therapy).

Do I have to take part?

No. Participation in this study is entirely voluntary, and whether or not you would like to be involved is up to you. If you decide that you would like to join the study, we will ask you to sign a consent form, to show that you understand the study and agree to take part in it. If however you join the study but then change your mind, you can leave at any time without giving a reason and we will destroy your data. Once you have completed all the sessions however, you will need to contact us within one month after your last session if you don't want us to include your responses in the final analysis.

What will I be asked to do if I take part?

We will ask you to attend up to three sessions. Within each session we will ask you to complete some short tasks, either to do with language, or with different thinking skills. Many of these tasks will be on the researcher's computer.

<u>First Step</u>

In Session 1, we will first carry out some tasks to make sure that you will be able to manage comfortably within the study, and are suitable to take part. We will first ask some questions about you (for example, your age). We will also ask you for the name of your GP and for an emergency contact.

After this, we will ask you to complete a brief task looking at general thinking skills, such as memory and attention. The test being used is a screening tool designed to detect decline in memory and other thinking skills. We will also ask you to complete a short questionnaire asking you 15 questions about your mood and general feelings of wellbeing, such as "Do you feel full of energy?". With your consent, the results from both of these tasks will be sent to your GP. If the tests indicate that you have particular difficulties with any of the tasks, we might decide not to continue with the study. In this case we will give you feedback, so that you can discuss any concerns in more detail with your GP.

If all these tasks indicate that you will be able to manage comfortably with the remaining tasks and you are happy to continue, we will carry on to the next step.

Second Step

Session 1: A few more tasks will be carried out in Session 1. In these tasks we will ask you to say some speech sounds, name some pictures of objects and listen to some sentences.

Session 2 and Session 3: These sessions will each be made up of 5 different tasks. Each session will contain some language and some thinking tasks.

The Language Tasks are:

• Naming Words • Saying a Sentence(s) • Describing an Event	You will be asked to either name a picture or say a sentence (or sentences) about a picture, or pictures.
• Saying a sentence from a given word or words	We will give you either one word or two words, and ask you to make a sentence using those words.
• Having a Conversation	We will have an informal conversation, e.g. about a holiday.

The Thinking Tasks are:

• Letter or Number Naming	You will see a letter and number printed on the computer screen, and be asked to name one of them.
• Colour Naming	You will be shown a word and asked to name the colour of the ink the word is printed in.
• Updating your Memory	You will be asked to decide whether the word on the screen is the same, or different, from the word presented two words earlier.
• Memory span	You will hear a list of numbers and be asked to repeat them back, either in the same order or in the opposite order.
• Shape Comparison	You will see a shape on the computer and be asked to say which side of the shape is longer.

Where will it take place?

The sessions will take place in your preferred location, either within your own home or within the University of Strathclyde. If you need to travel to the sessions, reasonable travel expenses will be reimbursed.

How long will it take?

The first session will take approximately 1 hour 30 minutes, and the second and third sessions will take approximately 1 hour 15 minutes each. This includes time for short breaks between tasks as required. Sessions will be a minimum of 3 days apart, but no more than 6 weeks apart. If there are 6 weeks between sessions, the mood, and general thinking skills task carried out at the start of the study may need to be carried out again.

What are the benefits for me in taking part?

There will be no immediate benefit available from taking part in the study, however it is hoped that the information gathered may be able to help guide therapy options to support individuals with Parkinson's Disease. We won't be able to return your individual results from the tasks to you, but can provide you with an overview of findings from the whole study once it has been completed, if you wish. A copy of this overview will also be sent to your GP.

Are there any disadvantages to me taking part?

There are no specific risks associated with any of the tasks we will ask you to perform. However, due to the number of tasks involved in the study, there is the possibility that you may become tired. If this does happen, the task will stop immediately and be picked up again when you are ready.

In addition, if you find any of the tasks uncomfortable or upsetting, we ask that you please let us know immediately. In any such instances, the session will either cease there or, if you feel happy to continue, that task can be left out. This will not stop you remaining in the study, if you wish to. The exception are the tasks looking at general thinking skills and mood which both need to be completed. If you do not feel comfortable with either of those tasks, the study will finish there.

Will my information be kept private?

The consent form you sign, your personal contact details and your emergency contact will be stored securely, in a locked facility within the University. This is the only information we will have from which you will be able to be identified. This information will be stored separately from the responses you give in the tasks and will not be shared with anyone without your permission. The information collected from the tasks will be anonymised using a study number allocated to you. This means that your name will not be on any of your responses.

Your responses from most of the tasks will be recorded onto the computer and/or a Dictaphone. After the session the research team will listen to the audio files and type up your responses. These transcriptions will be encrypted and uploaded to the University's secure data storage facility, along with the original audio recordings. Any responses to tasks which have been recorded on paper will either be transferred to a computer document or scanned, encrypted and also uploaded onto the secure University data storage facility. The original paper copy will then be destroyed. During the study, only members of the research team will have access to the information collected.

Results from the study will be presented as a PhD thesis, and might be published in a scientific journal, presented in a conference or used for other educational purposes. You will not be identifiable from any information presented.

If the researcher has significant concerns about your safety or wellbeing (for example, if you were to become unwell during a research session), the researcher will alert your GP and/or the emergency services. In the unlikely event of such an incident, only information absolutely necessary will be disclosed.

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What will happen to my information after the study has finished?

Once the study has finished, your personal information will be destroyed. We will keep all the other information collected from the study, including the audio recordings, in the University's secure research data depository, for 15 years. Only the research team will be able to access this data.

Who has reviewed this study?

This study has been approved by the NHS Research Ethics Committee.

Do you have any questions?

This information sheet is yours to keep. If you have any further questions about the study, please don't hesitate to contact a member of the research team below.

What do I do now?

Having read this information sheet, if you feel that you might like to be involved in the study, please fill in the response form at the end of this sheet and return it to us using the stamped, addressed envelope provided.

Contact Us:

Ms Rebecca Wagstaff	School of Psychological Sciences and Health University of Strathclyde, Graham Hills Building, 40 George Street Glasgow, G1 1QE **Tel:** 0141 548 4393 **Email**: rebecca.wagstaff@strath.ac.uk
Prof. Anja Lowit	School of Psychological Sciences and Health University of Strathclyde Graham Hills Building, 40 George Street Glasgow, G1 1QE **Tel:** 0141 444 8185 **Email**: a.lowit@strath.ac.uk

Insurance/Indemnity

The University of Strathclyde has insurance policies in place that cover professional indemnity of its staff and/or students.

If you have a complaint about any aspect of this study

If you are unhappy with any aspect of this study and wish to make a complaint, or discuss your concerns, please contact the Ethics Secretariat, University of Strathclyde, Graham Hills Building, 50 George Street, Glasgow, G1 1QE or call 0141 548 3298.

For information about how to make an NHS related complaint, please contact NHS Inform on 0800 22 44 88 or email nhs.inform@nhs24.scot.nhs.uk

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Language Production in Parkinson's Disease

Response Form

Thank you for taking the time to read the information about this research study.

If you feel that you would like to be involved, please fill in the details below and return this form using the stamped, addressed envelope provided. Sending us this form means that we can get in touch with you to explain the study in more detail. It does not commit you to taking part.

I confirm that I would like the research team to contact me regarding the research study outlined above.

Name: ______________________________ **Address:** ______________________________
____
____
____

Phone Number: ____________________ **Email Address:** ____________________________

If there are any times of day which would be preferable for us to contact you, please indicate them below.

____
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____

All information you provide here will be kept in the strictest confidence and will only be used to contact you about this study. This information will not be shared with anyone. If you choose to later withdraw from the study, this information will be destroyed.

Appendix B. Participant Information Sheet (Parkinson's Group)

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Language Production in Parkinson's Disease

We invite you to take part in a research study.

- We want to find out more about how Parkinson's Disease might affect the words, sentences and groups of sentences that people use. To do this, we are looking at how people complete different thinking and language tasks
- Whether you would like to join the study is entirely up to you.
- Before you decide, we ask that you read through the information in this sheet, so that you understand what the study is about, and what you would be asked to do.
- Please feel free to speak with family and friends about the study if you wish. If anything is unclear, or you have any questions, please don't hesitate to ask one of the research team now, or get in touch with us. Our details can be found at the end of this sheet.

Important things you need to know

- This study will involve two groups of participants – one group of individuals with Parkinson's Disease, and one group of individuals without Parkinson's Disease.
- With your consent, we will write to your GP to let them know that you are taking part in the study.
- This study will be completely separate from your normal healthcare appointments.
- We will ask you to attend up to 3 sessions; these can take place in your home, within the University or, subject to arrangement, at an NHS Lothian GP site.
- You are very welcome to have someone you know with you in the sessions, but you don't have to.
- We will audio record the spoken responses you give during the tasks.
- All the information collected from the tasks will be anonymised, using a unique code allocated to you.
- Unfortunately, if any of the following apply to you, you will not be able to join the study:
    - If you have had a stroke
    - If you have been diagnosed with another neurological condition
    - If you have a diagnosis of dementia
    - If you have a diagnosis of depression
    - If you have a speech and/or language impairment (that isn't related to your Parkinson's)
    - If you have vision or hearing impairment (that isn't fully corrected through the use of glasses or a hearing aid)
    - If you are younger than 50 years of age
    - If you were diagnosed with Parkinson's Disease before you were 50
    - If you have received Deep Brain Stimulation
    - If you live outside of Scotland
    - If you are not a native speaker of English

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What is this study about?

The aim of this study is to find out more about how Parkinson's Disease might affect the words, sentences and groups of sentences that people say. Being able to talk with other people is a huge part of our everyday life. We want to know more about why language changes may happen in Parkinson's Disease, so that we can better understand how to support individuals with such difficulties.

Who is carrying out the research?

The research is being carried out by Rebecca Wagstaff, a PhD student at the University of Strathclyde. Rebecca has a degree in Speech and Language Therapy and a Master's Degree in the Psychology of Language, and is being supervised by three staff members from the University of Strathclyde: Professor Anja Lowit (Speech and Language Therapy), Dr Louise Brown (Psychology) and Dr Anja Kuschmann (Speech and Language Therapy).

Do I have to take part?

No. Participation in this study is entirely voluntary, and whether or not you would like to be involved is up to you. If you decide that you would like to join the study, we will ask you to sign a consent form, to show that you understand the study and agree to take part in it. If however you join the study but then change your mind, you can leave at any time without giving a reason and we will destroy your data. Once you have completed all the sessions however, you will need to contact us within one month after your last session if you don't want us to include your responses in the final analysis.

What will I be asked to do if I take part?

We will ask you to attend up to three sessions. Within each session we will ask you to complete some short tasks, either to do with language, or with different thinking skills. Many of these tasks will be on the researcher's computer.

First Step

In Session 1, we will first carry out some tasks to make sure that you will be able to manage comfortably within the study, and are suitable to take part. We will first ask some questions about you (for example, your age) and about your Parkinson's Disease (for example, when you received a diagnosis, and the medication you take). We will also ask you for the name of your GP, Parkinson's Nurse (if applicable) and for an emergency contact. Don't worry if you can't remember all the information about your Parkinson's medication, or when you received the diagnosis – if you are happy for us to do so, we can speak with your GP or Parkinson's Disease Nurse to find out the information we need. Finally, we will ask you some questions about how you feel about your communication in everyday situations.

After this, we will ask you to complete a brief task looking at general thinking skills, such as memory and attention. The test being used is a screening tool designed to detect decline in memory and other thinking skills. We will also ask you to complete a short questionnaire asking you 15 questions about your mood and general feelings of wellbeing, such as "Do you feel full of energy?". With your consent, the results from both of these tasks will be sent to your GP. If the tests indicate that you have particular difficulties with any of the tasks, we might decide not to continue with the study. In this case we will give you feedback, so that you can discuss any concerns in more detail with your GP.

If all these tasks indicate that you will be able to manage comfortably with the remaining tasks and you are happy to continue, we will carry on to the next step.

Second Step

Session 1: A few more tasks will be carried out in Session 1. In these tasks we will ask you to say some speech sounds, name some pictures of objects and listen to some sentences. We will also speak with you a little more about how your Parkinson's affects you day to day. With your consent, we will contact your GP and/or another healthcare professional involved in your care (for example, the health care professional who gave you the information about this study) after the session to find out about the progression of your Parkinson's.

Session 2 and Session 3: These sessions will each be made up of 5 different tasks. Each session will contain some language and some thinking tasks.

The Language Tasks are:

• Naming Words • Saying a Sentence(s) • Describing an Event	You will be asked to either name a picture or say a sentence (or sentences) about a picture, or pictures.
• Saying a sentence from a given word or words	We will give you either one word or two words, and ask you to make a sentence using those words.
• Having a Conversation	We will have an informal conversation, e.g. about a holiday.

The Thinking Tasks are:

• Letter or Number Naming	You will see a letter and number printed on the computer screen, and be asked to name one of them.
• Colour Naming	You will be shown a word and asked to name the colour of the ink the word is printed in.
• Updating your memory	You will be asked to decide whether the word on the screen is the same, or different, from the word presented two words earlier
• Memory span	You will hear a list of numbers and be asked to repeat them back, either in the same order or in the opposite order.
• Shape Comparison	You will see a shape on the computer and be asked to say which side of the shape is longer.

Where will it take place?

We will ask you to attend up to 3 sessions; these can take place in your home, within the University or, subject to arrangement, at an NHS Lothian GP site. If you need to travel to the sessions, reasonable travel expenses will be reimbursed.

How long will it take?

The first session will take approximately 1 hour 30 minutes, and the second and third sessions will take approximately 1 hour 15 minutes each. This includes time for short breaks between tasks as required. Sessions will be a minimum of 3 days apart, but no more than 6 weeks apart. If there are 6 weeks between sessions, the mood, and general thinking skills task carried out at the start of the study may need to be carried out again.
Sessions will be arranged where possible to fit in with your medication schedule.

What are the benefits for me in taking part?

There will be no immediate benefit available from taking part in the study, however it is hoped that the information gathered may be able to help guide therapy options to support individuals with Parkinson's Disease. We won't be able to return your individual results from the tasks to you, but can provide you with an overview of findings from the whole study once it has been completed, if you wish. A copy of this overview will also be sent to your GP.

Are there any disadvantages to me taking part?

There are no specific risks associated with any of the tasks we will ask you to perform. However, due to the number of tasks involved in the study, there is the possibility that you may become tired. If this does happen, the task will stop immediately and be picked up again when you are ready.

In addition, if you find any of the tasks uncomfortable or upsetting, we ask that you please let us know immediately. In any such instances, the session will either cease there or, if you feel happy to continue, that task can be left out. This will not stop you remaining in the study, if you wish to. The exception are the tasks looking at general thinking skills and mood which both need to be completed. If you do not feel comfortable with either of those tasks, the study will finish there.

Will my information be kept private?

The consent form you sign, your personal contact details and your emergency contact will be stored securely, in a locked facility within the University. This information will be stored separately from the responses you give in the tasks and will not be shared with anyone without your permission. The information collected from the tasks will be anonymised using a study number allocated to you. This means that your name will not be on any of your responses.

Your responses from most of the tasks will be recorded onto the computer and/or a Dictaphone. After the session the research team will listen to the audio files and type up your responses. These transcriptions will be encrypted and uploaded to the University's secure data storage facility, along with the original audio recordings. Any responses to tasks which have been recorded on paper will either be transferred to a computer document or scanned, encrypted and also uploaded onto the secure University data storage facility. The original paper copy will then be destroyed. During the study, only members of the research team will have access to the information collected.

Results from the study will be presented as a PhD thesis, and might be published in a scientific journal, presented in a conference or used for other educational purposes. You will not be identifiable from any information presented.

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If the researcher has significant concerns about your safety or wellbeing (for example, if you were to become unwell during a research session), the researcher will alert your GP and/or the emergency services. In the unlikely event of such an incident, only information absolutely necessary will be disclosed.

What will happen to my information after the study has finished?

Once the study has finished, your personal information will be destroyed. We will keep all the other information collected from the study, including the audio recordings, in the University's secure research data depository, for 15 years. Only the research team will be able to access this data.

Who has reviewed this study?

This study has been approved by the NHS Research Ethics Committee.

Do you have any questions?

This information sheet is yours to keep. If you have any further questions about the study, please don't hesitate to contact a member of the research team below.

What do I do now?

Having read this information sheet, if you feel that you might like to be involved in the study, please fill in the response form at the end of this sheet and return it to us using the stamped, addressed envelope provided.

Contact Us:

Ms Rebecca Wagstaff	School of Psychological Sciences and Health University of Strathclyde, Graham Hills Building, 40 George Street Glasgow, G1 1QE **Tel:** 0141 548 4393 **Email:** rebecca.wagstaff@strath.ac.uk
Prof. Anja Lowit	School of Psychological Sciences and Health University of Strathclyde Graham Hills Building,40 George Street Glasgow, G1 1QE **Tel:** 0141 444 8185 **Email:** a.lowit@strath.ac.uk

Insurance/Indemnity

The University of Strathclyde has insurance policies in place that cover professional indemnity of its staff and/or students.

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If you have a complaint about any aspect of this study

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For information about how to make an NHS related complaint, please contact NHS Inform on 0800 22 44 88 or email nhs.inform@nhs24.scot.nhs.uk

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Language Production in Parkinson's Disease

Response Form

Thank you for taking the time to read the information about this research study.

If you feel that you would like to be involved, please fill in the details below and return this form using the stamped, addressed envelope provided. Sending us this form means that we can get in touch with you to explain the study in more detail. It does not commit you to taking part.

I confirm that I would like the research team to contact me regarding the research study outlined above.

Name: ______________________________ **Address:** ______________________________
____
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Phone Number: ____________________ **Email Address:** ____________________________

If there are any times of day which would be preferable for us to contact you, please indicate them below.

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All information you provide here will be kept in the strictest confidence and will only be used to contact you about this study. This information will not be shared with anyone. If you choose to later withdraw from the study, this information will be destroyed.

Appendix C. Cognitive Screening Tool

The Mini Addenbrooke's Cognitive Examination (Hsieh et al., 2015; form retrieved from https://sydney.edu.au/brain-mind/resources-for-clinicians/dementia-test.html)

MINI – ADDENBROOKE'S COGNITIVE EXAMINATION
UK Version A (2014)

Name: Date of Birth: Hospital No. or Address:	Date of testing: ____/___/___ Tester's name:______________________________ Age at leaving full-time education:______________ Occupation: ______________________________ Handedness: ______________________________

ATTENTION

➢ Ask: What is the	Day _________	Date _________	Month _________	Year _________	**Attention** [Score 0-4]

MEMORY

➢ Tell: "I'm going to give you a name and address and I'd like you to repeat the name and address after me. So you have a chance to learn, we'll be doing that 3 times. I'll ask you the name and address later."

Score only the third trial.

Memory
[Score 0 – 7]

	1st Trial	*2nd Trial*	*3rd Trial*
Harry Barnes	________ ________	________ ________	________ ________
73 Orchard Close	____ ______ ______	____ ______ ______	____ ______ ______
Kingsbridge	______________	______________	______________
Devon	______________	______________	______________

FLUENCY – ANIMALS

➢ **Animals**
Say: "Now can you name as many animals as possible. It can begin with any letter. You have one minute. Go ahead."

Fluency
[Score 0 – 7]

≥ 22	7
17-21	6
14-16	5
11-13	4
9-10	3
7-8	2
5-6	1
<5	0
total	correct

CLOCK DRAWING

➢ Clock: Ask the subject to draw a clock face with numbers and the hands at ten past five. (For scoring see instruction guide: circle = 1, numbers = 2, hands = 2 if all correct).	**Visuospatial** [Score 0-5]

MEMORY RECALL

➢ Ask "Now tell me what you remember about that name and address we were repeating at the beginning"

Harry Barnes	....	**Memory** [Score 0-7]
73 Orchard Close	....	
Kingsbridge	....	
Devon	....	

TOTAL SCORE	**/ 30**

Updated 25/05/2014

Appendix D. Depression Screening Tool

The Geriatric Depression Scale-15 (GDS-15; Yesavage & Sheikh, 1986; form retrieved from: https://dementiapathways.ie/_filecache/0c8/57e/37-gds.pdf)

Geriatric Depression Scale (Short Form)
Self-Rated Version

Patient's Name: ______________________________ Date: ______________

***Instructions*: Choose the best answer for how you felt over the past week.**

No.	Question	Answer	Score
1.	Are you basically satisfied with your life?	YES / NO	
2.	Have you dropped many of your activities and interests?	YES / NO	
3.	Do you feel that your life is empty?	YES / NO	
4.	Do you often get bored?	YES / NO	
5.	Are you in good spirits most of the time?	YES / NO	
6.	Are you afraid that something bad is going to happen to you?	YES / NO	
7.	Do you feel happy most of the time?	YES / NO	
8.	Do you often feel helpless?	YES / NO	
9.	Do you prefer to stay at home, rather than going out and doing new things?	YES / NO	
10.	Do you feel you have more problems with memory than most people?	YES / NO	
11.	Do you think it is wonderful to be alive?	YES / NO	
12.	Do you feel pretty worthless the way you are now?	YES / NO	
13.	Do you feel full of energy?	YES / NO	
14.	Do you feel that your situation is hopeless?	YES / NO	
15.	Do you think that most people are better off than you are?	YES / NO	
		TOTAL	

(Sheikh & Yesavage, 1986)

Appendix E. Individual Participant Characteristics

Table 39.

Individual participant characteristics in the Parkinson's (PD) and Control (CP) group

Participant	Age[ab]	Gender	Education	Years Since Diagnosis[a]	Side of Body Most Affected[a]	Parkinson's Medication	Form of Levodopa?
PD001	69	F	Further Education	3	Not Observed	Yes	Yes
PD002	77	F	Further Education	22	Right	Yes	Yes
PD003	75	M	Postgraduate Education	16	Not Observed	Yes	Yes
PD004	66	F	Further Education	7	Left	Yes	Yes
PD005	68	F	Postgraduate Education	6	Left	Yes	Yes
PD006	81	M	School Level	8	Right	Yes	Yes
PD007	79	M	Further Education	3	Right	Yes	Yes
PD008	59	F	Further Education	9	Right	Yes	Yes
PD009	73	F	Postgraduate Education	3	Right	Yes	Yes
PD010	61	M	Postgraduate Education	1	Right	Yes	Yes
PD011	76	F	School Level	5	Right	Yes	Yes
PD012	77	M	Further Education	1	Left	No	N/A
PD013	57	F	School Level	5	Left	Yes	Yes
PD014	69	F	Postgraduate Education	8	Left	Yes	Yes
PD015	81	M	Postgraduate Education	2	Right	Yes	Yes

PD016	73	M	Further Education	5	Right	Yes	Yes
CP001	64	F	Postgraduate Education	N/A	N/A	N/A	N/A
CP002	79	F	Further Education	N/A	N/A	N/A	N/A
CP003	67	F	Further Education	N/A	N/A	N/A	N/A
CP004	83	F	Further Education	N/A	N/A	N/A	N/A
CP005	64	M	Postgraduate Education	N/A	N/A	N/A	N/A
CP006	76	M	Further Education	N/A	N/A	N/A	N/A
CP007	67	F	Further Education	N/A	N/A	N/A	N/A
CP008	75	M	Further Education	N/A	N/A	N/A	N/A
CP009	56	M	Further Education	N/A	N/A	N/A	N/A
CP010	66	F	School Level	N/A	N/A	N/A	N/A
CP011	68	F	School Level	N/A	N/A	N/A	N/A
CP012	83	F	Further Education	N/A	N/A	N/A	N/A
CP013	74	F	Further Education	N/A	N/A	N/A	N/A
CP014	81	F	School Level	N/A	N/A	N/A	N/A
CP015	68	F	Further Education	N/A	N/A	N/A	N/A
CP016	74	F	Further Education	N/A	N/A	N/A	N/A
CP017	68	M	Further Education	N/A	N/A	N/A	N/A
CP018	68	M	School Level	N/A	N/A	N/A	N/A
CP019	92	F	Further Education	N/A	N/A	N/A	N/A
CP020	68	M	School Level	N/A	N/A	N/A	N/A

CP021	78	F	School Level	N/A	N/A	N/A	N/A
CP022	74	F	Further Education	N/A	N/A	N/A	N/A
CP023	67	F	Postgraduate Education	N/A	N/A	N/A	N/A
CP024	82	F	Further Education	N/A	N/A	N/A	N/A
CP025	66	F	Postgraduate Education	N/A	N/A	N/A	N/A

[a]At the time of the study.

[b]Age reported to nearest year. For the purposes of group matching, data to two decimal places utilised.

Appendix F. Schwab and England Activity of Daily Living Scale

Schwab and England Activity of Daily Living Scale

100%–completely independent; able to do all chores without slowness, difficulty, or impairment; essentially normal; unaware of any difficulty

90%–completely independent and able to do all chores with some degree of slowness, difficulty, or impairment; some activities might take twice as long; beginning to be aware of difficulty

80%–completely independent in most chores; some activities take twice as long; conscious of difficulty and slowness

70%–not completely independent; more difficulty with some chores; some tasks now take three to four times as long; must spend a large part of the day with chores

60%–some dependency; can do most chores, but exceedingly slowly and with much effort; some tasks cannot be done; common errors

50%–more dependent; needs help with about half of activities; slower and experiencing difficulty with all tasks

40%–very dependent, but still able to assist with all chores; however, few can be done independently

30%–all tasks require much effort; a few chores can be done alone or at least started alone; much assistance needed

20%–no tasks done independently; patient can provide slight help with some chores; but requires substantial assistance for all activities

10%–totally dependent and requires assistance with all activities of daily living

0%–vegetative functions with loss of control of swallowing, bladder, and bowel functions; Bedridden

Scale retrieved from: *Perlmutter, J. S. (2009). Assessment of Parkinson disease manifestations. Current Protocols in Neuroscience, Chapter 10, Unit10.1. http://doi.org/10.1002/0471142301.ns1001s49*

Appendix G. Alterations made to tasks following the pilot stage.

All changes made to the task materials, procedures and protocol following the pilot study are detailed below. Any feedback from participants was noted and fed into these changes, as appropriate.

Practice Sessions

Although in the pilot study practice sessions were included for the cognitive tasks, there were no practice sessions for the language tasks. Following the pilot it was noted that some individuals were being very ‘broad’ in their description of the picture they were seeing. Thus, the decision was taken to include a practice session within each task, giving participants the chance to see the pictures and get a feeling for what they were to be focusing on.

In order to ensure that all the language tasks followed the same protocol (and thus to ensure accurate comparisons were able to be made across the tasks), practice sessions were included within all language tasks.

Materials

Patterns of errors made in the picture naming tasks were evaluated and, where any such errors appeared to be caused by an aspect of the materials which could be adapted, the appropriate adaptations were made. This involved changing the focus of the picture, either through zooming into the noun or action of interest and/or adding an arrow into the picture so that the protagonist of the action of interest or the object of interest was highlighted. One picture stimulus (target verb ‘sob’) was replaced with a pre-prepared alternative (which was comparable in form), due to it being impossible to edit the picture without distorting it.

Any errors evident in the randomised materials were corrected. Specifically, the repetition of one nonsense word in the speech initiation task (and consequent omission of another nonsense word) was corrected, and some number strings in the working memory task were replaced by newly generated number strings, to control the number of stepwise patterns in each string (up to a maximum of one stepwise pair in strings up to six numbers long and two stepwise pairs in strings of seven-nine numbers).

Procedure and Instructions

Changes to the procedure followed within tasks are outlined below.

Verb Naming Task

To encourage people to focus on the target verb (rather than picture more broadly), the instruction wording was altered slightly to explicitly request that individuals name the action that they see taking place as *specifically* as they can. This instruction was emphasised within the practice session and an example given by the researcher if required.

Sentence Production Task

It was noticed that, in the sentence production task particularly, what was happening in the picture was described very broadly by participants. As well as adding arrows into the pictures, a sentence starter was added immediately underneath the picture, steering individuals towards the person in the picture who was doing the action of interest (e.g., *'the man is…'*). To accommodate the sentence starter, the picture size was reduced slightly to 293x440 pixels.

As with the verb naming task above, individuals were asked to describe the action that they saw taking place as *specifically* as they could. The task instructions were also changed slightly to ‘please say the sentence as soon as you can *once you have thought of it*’, in an effort to prevent participants responding immediately upon seeing the stimulus but then pausing because their sentence was not fully thought of (as evident within the pilot).

One Word Sentence Generation Task

The instructions for this task were altered as per the sentence production task above, with individuals asked to say their sentence as soon as they could *once they had thought of it*.

Updating

An additional independent variable of ‘speed’ was added to the updating task, trialled in the second half of the pilot. For two of the blocks, the ISI between words was shortened to 3000ms. Additional stimuli were also added on to this ‘fast’ block, to lengthen the overall sequence.

From looking at the data following the pilot, it was evident that errors were actually made in both conditions. Interestingly, of those who made errors in the faster condition, in most cases the majority were actually in the first half of the sequence. Thus, the decision was taken to keep the updating sequences at the same length (at eight words) but to have two blocks with a longer ISI (slight reduced from the pilot study to 6000ms) and two blocks with a shorter ISI (3000ms). The stimuli presentation time for both conditions was 1000ms.

Having the two condition allows for useful comparisons regarding individuals’ performance dependent on the length of ISI. For all participants, the two slower blocks were completed before the faster blocks. The practice sessions were made up of ‘slower’ blocks (stimulus presentation time 1000ms, ISI 6000ms) and individuals completed as many of these as was needed to feel confident in the task.

Participants were not informed of the number of words to expect per sequence, if an effort to ensure that their attention was maintained.

Processing Speed

Following feedback from a participant that they were not ready for the stimulus to appear in the processing speed task, the wording was adapted to prepare people to be ready for the stimuli to appear quickly upon clicking to summon it.

Appendix H. Word List for the Speech Initiation Task

Table 40.

Nonsense word list for the speech initiation task (voiced consonants)

	Consonant	Place	CV nonsense word
Plosives	b	Bilabial	bee, booh, bah
	d	Alveolar	dee, dooh, dah
	g	Velar	gee, gooh, gah
Affricates	dʒ	Palato-alveolar	jee, jooh, jah
Fricatives	v	Ladiodental	vee, vooh, vah
	ð	Dental	thee, thooh, thah
	z	Alveolar	zee, zooh, zah
	ʃ	Palato-alveolar	shee, shooh, shah
	h	Glottal	hee, hooh, hah
Nasals	m	Bilabial	mee, mooh, mah
	n	Alveolar	nee, nooh, nah

Table 41.

Nonsense word list for the speech initiation task (voiceless consonants)

	Consonant	Place	CV nonsense word
Plosives	p	Bilabial	pee, pooh, pah
	t	Alveolar	tee, tooh, tah
	k	Velar	kee, kooh, kah
Affricates	tʃ	Palatal-alveolar	chee, chooh, chah
Fricatives	f	Ladiodental	fee, fooh, fah
	s	Alveolar	see, sooh, sah
Approximants	w	Bilabial	wee, wooh, wah
	l	Alveolar	lee, looh, lah
	r	Post-alveolar	ree, rooh, rah
	j	Palatal	yee, yooh, yah

Appendix I. Word List for the Noun Naming Task

Table 42.

Word list utilised within the noun naming task, according to motion condition

Group	Nouns	
High Level of Associated Motion (animate)	sheep	seahorse
	girl	bat
	kangaroo	beetle
	ladybird	rabbit
	baboon	zebra
	snake	dog
	pig	giraffe
Some Associated Motion	axe	toothbrush
	balloon	syringe
	sword	helicopter
	spade	eye
	dart	saw
	volcano	pen
	parachute	football
No Associated Motion	table	saddle
	bath	wall
	lightbulb	honey
	cathedral	ladder
	easel	sofa
	pyramid	pear
	oven	lanyard

Appendix J. Word list for the Verb Naming Task

Table 43.

Word list utilised within the verb naming task, according to action and the number of syntactic arguments taken by the verb (transitivity). NB: this same list was utilised in the general profile, collapsed across conditions)

	Intransitive# (1 argument)	Transitive Optional (1 or 2 arguments)	Transitive (2 arguments)	Ditransitive Optional (up to 3 arguments)
Low Action	Sunbathe	Wait	Ignore	Prescribe
	Listen	Spit	Baptize	Write
	Snore	Steal	Recycle	Read
	Chat	Count	Wring (out)	Pour
	Look	Shave	Sprinkle	Pick
	Scowl	Cry	Unlock	Feed
	Kneel	Salute		Knit
		Donate		
High Action	Stumble	Clap	Unload	Serve
	Sneeze	Celebrate	Examine	Teach
	Tiptoe	Juggle	Extinguish	Throw
	Sob	Walk	Chop	Bake*
	Crawl	Swallow	Mow	Make
	Fall	Wrestle	Whisk	Cook*
	Collide	Swim	Bury	Build

*It is acknowledged that both ‘cook’ and ‘bake’ are ergative verbs and can take an unaccusative structure. However, because, as Kilgarriff (1993) discuss, both verbs are different to other ergatives in that an agent is somewhat implied (a person has instigated the process of putting the bread in the oven and baking it, for example), and as both verbs can take an ‘unspecified object alternation’ – i.e., they can take an intransitive form whereby the subject is the agent (e.g., ‘My mother cooks brilliantly’, ‘My Mum bakes on a Sunday’) – they were considered appropriate to be included in this verb list. To avoid any use of the ergative form when creating a sentence using a given verb, individuals were asked to use a person at the start of the sentence.

#It is acknowledged that some verbs within the list are unaccusative, such that the person in the sentence is acting semantically as the theme rather than the agent. This was unavoidable, due to the restrictions the conditions placed, however was borne in mind.

Appendix K. Verb Rating: Number of ratings per stimulus.

Table 44.

Number of participants who provided an action rating for each verb

	Low Action		High Action	
	Word	*n*	Word	*n*
Intransitive	Sunbathe	17	Stumble	33
	Listen	17	Sneeze	32
	Snore	21	Tiptoe	33
	Chat	26	Sob	29
	Look	22	Crawl	33
	Scowl	20	Fall	33
	Kneel	27	Collide	33
Transitive Optional	Wait	16	Clap	33
	Spit	32	Celebrate	29
	Steal	31	Juggle	33
	Count	21	Walk	33
	Shave	32	Swallow	30
	Cry	28	Wrestle	33
	Salute	31	Swim	33
	Donate	21		
Transitive	Ignore	15	Unload	32
	Baptize	29	Examine	24
	Recycle	21	Extinguish	28
	Wring	28	Chop	30
	Sprinkle	30	Mow	31
	Unlock	29	Whisk	31
			Bury	31
Ditransitive Optional	Prescribe	20	Serve	30
	Write	33	Teach	27
	Read	22	Throw	32
	Pour	31	Bake	33
	Pick	25	Make	31
	Feed	27	Cook	32
	Knit	31	Build	33

Appendix L. Number-letter pair list for the Set Shifting task

Table 45.

Number-letter pair stimuli utilised within the set shifting task, according to block

	Block 1		Block 2	
Number-letter pairs	6 N	R 4	6 Y	5 N
	3 F	6 K	4 Y	5 K
	F 6	4 F	N 6	N 4
	2 R	K 4	2 R	N 5
	3 K	N 3	6 N	Y 2
	K 4	R 6	Y 4	3 F
	F 4	F 2	3 Y	K 2
	Y 5	N 5	N 2	K 3
	2 K	6 F	R 4	2 F
	R 5	F 3	Y 5	Y 3
	4 R	N 6	R 3	4 K
	5 R	4 K	R 6	2 K
	K 3	Y 2	3 R	F 3
	3 N	2 F	3 N	F 4
	K 6	Y 3	K 4	2 Y
	4 Y	3 R	F 5	F 6
	Y 4	6 R	5 F	2 N
	N 4	6 Y	4 F	K 4
	K 2	5 K	N 3	6 K
	Y 6	5 F	5 R	6 R

Appendix M. Word and symbol list for the Inhibition Task

Table 46.

Stimuli utilised within the inhibition (Stroop) task and order of presentation per trial block

	Block 1		Block 2		Block 3	
	Word/ Symbol	Colour	Word/ Symbol	Colour	Word/ Symbol	Colour
Stimulus	red	green	red	yellow	red	purple
	####	red	old	purple	quick	green
	quick	green	old	green	old	red
	####	purple	lively	yellow	yellow	green
	red	yellow	purple	red	####	yellow
	lively	green	quick	yellow	lively	green
	purple	red	clever	red	purple	yellow
	purple	green	quick	yellow	green	red
	red	red	old	red	clever	purple
	green	purple	purple	green	red	green
	green	red	quick	purple	lively	red
	yellow	purple	green	green	####	purple
	####	yellow	green	purple	clever	red
	clever	red	red	green	green	green
	lively	purple	purple	yellow	green	purple
	old	red	####	red	yellow	yellow
	lively	yellow	lively	purple	red	red
	green	green	red	yellow	quick	purple
	yellow	red	green	purple	lively	yellow
	####	green	lively	red	red	purple
	purple	yellow	yellow	yellow	old	green
	clever	green	clever	green	quick	yellow
	quick	yellow	####	yellow	purple	red
	old	purple	yellow	red	old	yellow
	purple	red	yellow	purple	purple	purple
	green	yellow	lively	green	####	green
	red	purple	####	yellow	yellow	purple
	old	yellow	purple	purple	yellow	yellow

	green	red	green	green	purple	green
	quick	purple	clever	yellow	####	purple
	lively	red	####	green	red	yellow
	yellow	yellow	red	red	green	red
	yellow	green	quick	green	old	purple
	quick	red	clever	purple	clever	yellow
	purple	purple	green	red	yellow	green
	clever	yellow	yellow	green	green	yellow
	####	green	green	yellow	quick	red
	yellow	purple	red	purple	purple	yellow
	red	green	purple	green	yellow	red
	clever	purple	yellow	red	clever	green
	old	green	####	purple	####	red
	red	red	old	yellow	lively	purple

Appendix N. Word Lists for the Updating Task

Table 47.

Word lists utilised within the updating task

Block	Word List (Target, Foil)
1	pot, arm, pot, kid, arm, kid, arm, pot
2	arm, kid, pot, arm, pot, arm, kid, arm
3	pot, kid, arm, kid, pot, kid, arm, kid
4	kid, arm, kid, arm, pot, kid, arm, kid

Appendix O. Number Sequences for the Digit Span Tasks

Table 48.

Number sequences utilised within the digit span tasks

	Forwards		Backwards	
	List Length	List	List Length	List
Number Sequence	2	4, 9	2	1, 7
		3, 7		1, 4
		4, 1		6, 1
	3	5, 4, 1	3	6, 5, 9
		4, 6, 1		1, 8, 9
		6, 2, 3		5, 2, 8
	4	1, 7, 5, 6	4	4, 7, 6, 2
		6, 7, 9, 4		6, 3, 7, 5
		5, 9, 2, 3		7, 1, 3, 8
	5	4, 3, 9, 5, 2	5	4, 3, 9, 2, 6
		5, 8, 1, 7, 2		1, 8, 2, 6, 5
		3, 6, 7, 9, 4		6, 4, 8, 5, 3
	6	2, 8, 3, 7, 9, 6	6	9, 2, 3, 7, 1, 5
		9, 6, 7, 2, 5, 1		8, 1, 9, 2, 7, 4
		4, 3, 8, 2, 9, 6		1, 4, 6, 9, 2, 5
	7	4, 7, 9, 3, 5, 1, 6	7	8, 9, 6, 4, 5, 7, 1
		2, 5, 3, 8, 6, 9, 1		5, 1, 6, 3, 8, 7, 4
		7, 4, 1, 2, 6, 9, 3		3, 5, 1, 7, 4, 9, 6
	8	4, 9, 3, 5, 6, 8, 1, 7	8	3, 2, 5, 1, 7, 6, 9, 4
		8, 7, 3, 6, 9, 1, 5, 4		1, 9, 7, 8, 6, 3, 2, 5
		4, 8, 5, 2, 7, 9, 6, 1		4, 3, 6, 8, 2, 7, 1, 9
	9	4, 3, 8, 5, 6, 2, 7, 1, 9	9	5, 7, 3, 9, 1, 4, 8, 2, 6
		7, 5, 2, 8, 6, 9, 4, 1, 3		1, 3, 7, 9, 5, 2, 6, 8, 4
		9, 2, 8, 6, 7, 4, 5, 3, 1		7, 1, 9, 2, 6, 8, 5, 3, 4

Appendix P. Figure presentation order in the Processing Speed (Visual Inspection Time) task

Table 49.

Order of stimuli presentation in the visual inspection time task

Block and Duration	Order of pi figures (longer side indicated)
1 (150ms)	left, right, right, left, left, right
2 (125ms)	right, left, right, right, left, left
3 (102ms)	left, right, right, left, right, left
4 (85ms)	left, right, left, left, right, right
5 (68ms)	left, right, right, right, left, left
6 (51ms)	right, right, left, left, right, left
7 (34ms)	left, left, right, left, right, right
8 (17ms)	left, right, left, right, right, left

Appendix Q. Word List for the Two Word Sentence Generation Task

Table 50.

Word-pairs used in the two word sentence generation task, as a function of relatedness

Group	Verb	Noun
Highly Related	sing	audition
	sneak	door
	propose	restaurant
	unpack	holiday
	prepare	interview
Loosely Related	revise	sunshine
	wriggle	mosquito
	beg	gallery
	shout	river
	applaud	poetry