Jargon Busting: The cognitive mechanisms underpinning nonword errors and perseveration in Jargon aphasia

A thesis submitted in fulfilment of the requirements for the degree of:

Doctor of Philosophy

School of Psychology and Clinical Language Sciences

University of Reading

Emma Pilkington

October 2019

Table of Contents

List of Tables

List of Figures

This page is intentionally left blank

Abstract

Jargon aphasia is a term used to refer to an acquired language disorder after stroke where high proportions of nonword error are produced in spoken output, reducing the intelligibility of speech and limiting communication effectiveness. A number of theoretical hypotheses have been proposed to explain nonword production in Jargon aphasia; the major hypotheses implicate lexical and phonological error sources. However, there exist few experimental studies testing these accounts. This thesis presents three studies which explore contributions from lexical and phonological processes to nonword error and Jargon production, drawing on data from twenty people with Jargon-like production deficits post-stroke.

The first experimental chapter explores nonword error patterns in Jargon aphasia across word production tasks with different lexical-phonological demands – reading, repetition, and naming, to examine whether phonological and/or lexical error sources can account for the observed patterns. The second experimental chapter analyses whether poor activation of phonological information from lexical selection mechanisms can account for error patterns in Jargon aphasia. To test this target word sets with different lexical availability, indexed by lexical-semantic properties associated with lexical retrieval, were used in tasks of single word repetition and reading. Crucially, these word sets were matched for their phonological processing demands. The third experimental chapter analyses whether inhibitory deficits contribute to the Jargon aphasia profile by manipulating the inter-stimulus time and tasks demands in between target words in reading aloud, to target the post-production time window associated with inhibitory processing after word production. Group and case-series analyses were implemented in all three experimental studies.

Results demonstrate that Jargon quantity is increased in tasks which have greater phonological demands, indicating a significant contribution from phonological processing to Jargon nonword error production. The success of phonological production was not consistently influenced by lexical availability, suggesting that greater amounts of lexical activation do not better inform phonological processing and implies that the phonological system is not able to utilise lexical-semantic activation effectively. The

third study indicated that inhibitory processes could be manipulated in some people with Jargon aphasia, suggesting that problems inhibiting phonological material post-production contribute to the Jargon presentation for some individuals; however this was not a universally contributing factor in Jargon production. Overall, results suggest that people with Jargon aphasia consistently present with phonological impairments; however, additional impairments in lexical-semantics and inhibitory processing may also contribute to the Jargon presentation. Results suggest that, for some people with Jargon aphasia, activation (of lexical-semantics) and inhibition processes can be manipulated to minimise the quantity and severity of Jargon production. However, many participants demonstrated stable and consistent patterns of production despite the experimental manipulations, suggesting severe phonological processing impairment which is resistant to lexical-semantic and inhibitory variables.

Declaration

All papers submitted in this thesis form original research studies, not submitted in support of application for another degree or qualification at this or any other university or other institute of learning. Data presented in Chapters 2 and 3 were collected for previously published research studies by Robson, Sage and Lambon Ralph (2012) and Robson, Grube, Lambon Ralph, Griffiths, and Sage (2012).

Thesis structure

This thesis is presented as a collection of papers. The papers, which are presented in manuscript form, form Chapters 3, 4 and 5. Chapter 3 is a published article in the Journal of Neurolinguistics and Chapter 4 is in press for publication in the Journal of Language, Cognition and Neuroscience. Chapter 5 will be submitted for publication following thesis completion. Chapter 1 includes a literature review and an introduction which outlines the aims of the papers presented as thesis chapters. Chapter 2 considers the behavioural and neurological profile associated with the Jargon participants presented in the papers and describes the recruitment process as part of data collection for this thesis. Chapter 6 is a general discussion chapter which considers and integrates the findings from the experimental chapters.

Acknowledgements

The brilliant experience of this PhD is largely down the inspirational supervision I have received over the past five years. Dr. Holly Robson, Professor Karen Sage and Professor Doug Saddy have been on hand throughout the process, from supporting my funding application in 2014 to reviewing the final discussion of this thesis in 2019. Their continued support throughout my studies has facilitated my professional (both academic and clinical) and personal development. Thanks to Doug for providing positive support and interesting thoughts from a linguists perspective, thanks to Karen for strategic and detailed consideration of all results and providing an experienced clinical perspective on this work, and finally thanks to Holly for her careful and exhaustive consideration of everything I have ever presented to her. A special thanks goes to Holly as my primary supervisor, who has treated me like an equal and an independent scientist from day one. Her approach allowed me to be curious and develop an enjoyment of academic work. In addition to her constructive support, Holly is a brilliant friend who cares deeply about the wellbeing of everyone and does whatever she can to help and support people in getting where they need/want to be. Holly – you are my inspiration as both a scientist and a brilliant human!

My thanks are extended to everyone in the School of Psychology and Clinical Language Sciences at Reading who are fabulous colleagues, especially the clinical tutors who helped me to adapt to my teaching responsibilities so effectively. I also want to thank the Acquired Brain Communication Disorders (ABCD) Lab, especially Lotte Meteyard and Arpita Bose, for providing interesting feedback whenever I presented my work in lab meetings. Huge thanks to my office nerds (Ines, Jo and Lucas) for always helping me laugh whenever I needed to and to my 207 office friends (Emily and Anthony) for providing support during my writing times.

This work was made possible by a postgraduate Stroke Association fellowship which was awarded to me and my supervisory team in 2015. This opportunity has changed my life and I am hugely grateful to the Stroke Association for investing in me and my career. I hope to continue this line of work and make a difference to people with aphasia. The biggest thanks must go to the twenty research participants and their families who contributed to the work which enabled to me to complete this thesis – you are the most resilient people I know. You make me feel humble and I will forever remember you and be grateful for your dedication to this work.

Final thanks go to my family (Mum, Dad, Rach, Amy) who have no idea what I do but have remained interested and supportive throughout, and to Asad for your wisdom, support and love.

Chapter 1. Introduction

1.1 *Profile and aphasia associations*

When Jargon aphasia was first documented it was described as production of a meaningless series of speech sounds (Bastian, 1869), thought to reflect uninhibited production of language components. A later classification from Alajouanine, Sabouraud, and De Ribaucourt (1952) extended this description and identified different subtypes of Jargon: asemantic – production of semantically inappropriate words; neologistic – high proportions of nonword errors produced alongside intact constructions; and undifferentiated – when production comprised nonwords exclusively. The semantic subtype is easily separable from the neologistic and undifferentiated subtypes since it does not involve the production of nonwords. However, differentiating between the neologistic and undifferentiated subtypes is more difficult because a spectrum of impairments is observed across the two and, therefore, they are not clearly dissociable. For this reason, when the terminology 'neologistic Jargon' is used in the current thesis, it is referring to both the neologistic and the undifferentiated forms. Nonwords have been and remain a particular source of interest since their first description, because their presence and dominance in output is not easily explicable within existing frameworks of language processing. Additionally, such production rarely arises in people without neurological injury or disease, and studies that have attempted to elicit nonword errors have failed to obtain the same quality and quantity of errors (Baars, Motley, & MacKay, 1975; Goldrick & Blumstein, 2006). Therefore, the production of nonwords and the aphasia subtype of Jargon aphasia, which is characterised and defined by their presence, is a source of controversy and interest.

Despite this interest, there has been little development in refining the Jargon aphasia definition in recent years. The label Jargon aphasia is not often adopted in the diagnosis of acquired language disorders nor is it included in the traditional language assessments used when diagnosing aphasia type (Boston Diagnostic Aphasia Examination: BDAE, Goodglass, Kaplan & Barresi, 2000; Western Aphasia Battery, Kertesz, 2006). This is partly because Jargon aphasia characteristics are observed in numerous types of acquired aphasia. These include conduction aphasia, characterised by preserved comprehension with impaired repetition (Baldo, Klostermann, & Dronkers, 2008; Brown, 1975; Goodglass, 1992), transcortical sensory aphasia, characterised by poor auditory comprehension with relatively spared repetition

(Berthier, 1995; 1999; Corbett, Jefferies, & Ralph, 2008) and, more commonly, Wernicke's aphasia, which is characterised by poor auditory processing and comprehension and impaired repetition (Dronkers & Baldo, 2010; Ellis, Miller, & Sin, 1983; Robson, Keidel, Lambon Ralph, & Sage, 2012). In all of these aphasia presentations phonemic paraphasias and/or neologistic nonwords may occur and consequently the Jargon label may be applied in addition to the traditional aphasia subtype labeling (Buckingham & Kertesz, 1974).

1.2 *Jargon aphasia neurology*

Jargon aphasia is associated with lesions to the posterior temporo-parietal region within which the posterior superior temporal gyrus and supramarginal gyrus are particularly associated with Jaron production (Buchsbaum et al., 2011; Kertesz, 1981; Kertesz & Benson, 1970; Kohn, Smith, & Alexander, 1996; Pilkington et al., 2017). The lesion patterns associated with conduction aphasia, transcortical sensory aphasia and Wernicke's aphasia intersect at these regions, indicating a degree of consistency in the cognitive and neurobiological sources of Jargon aphasia, despite its manifestation within different aphasia subtypes (Burns & Canter, 1977; Kreisler et al., 2000; Stuss et al., 1998). The temporo-parietal regions which are commonly affected in Jargon aphasia have been shown to support phonological, lexical and semantic linguistic functions. For example, the superior temporal gyrus and superior temporal sulcus are associated with phonological analysis, self-monitoring and translation of sensory to motor codes (Binder, 2018; Graves et al., 2003; Indefrey & Levelt, 2004). The supramarginal gyrus is associated with phonological processing for speech production and with temporarily storing phonological information, and wider temporo-parietal regions e.g. middle temporal gyrus and angular gyrus are more commonly associated with semantic or lexical processing (Damian & Martin, 1998; Price, 1998). Neuropsychological evidence from people with Jargon aphasia demonstrates the presence of sensory-motor deficits, for example, an impaired ability to self-monitor and correct erroneous speech (Kinsbourne & Warrington, 1963; Marshall, Robson, Pring, & Chiat, 1998; Panzeri, Semenza, & Butterworth, 1987), conforming with this neurobiological evidence. This thesis explores the contribution of lexical and phonological factors to nonword production in Jaron aphasia.

1.3 *Jargon aphasia nonwords*

Nonword error production is one of the most common features of Jargon aphasia and these errors are observed across different production tasks, including single word naming, reading and repetition (Brown, 1981; Marshall, 2006). The presence of nonwords significantly contaminates production and can render speech incomprehensible (Butterworth, 1979; Kinsbourne & Warrington, 1963). Therefore, clinical tasks often aim to reduce nonword quantity and severity. Therapeutic efficacy has rarely been assessed for Jargon participants; however, a small number of studies report positive outcomes, documenting improvement in nonword quality, naming and writing abilities (Bose, 2013; Bose, Höbler, & Saddy, 2019; Robson, Pring, Marshall, Morrison, & Chiat, 1998; Robson, Marshall, Pring, & Chiat, 1998). Having said this, other reports have failed to link production gains to the therapy tasks or have demonstrated little change in spoken production after treatment (Robson, Marshall, Chiat, & Pring, 2001; Robson et al., 1998). These conflicting accounts imply that therapy is not effectively targeting the underlying impairment in Jargon and suggest that better understanding of the cognitive-linguistic impairment associated with Jargon nonword production is needed. To this end, current methodologies have rigorously examined the phonological content of nonwords in Jargon and related observed error patterns back to neuropsychological and cognitive models of word processing, to support identification of affected processes. For example, the nonword response /wɪtwɪm/ produced to the target "witness" exhibits a relatively high proportion of target phonology and appears to have been generated with reference to the target lexical and phonological information. However, the nonword response /bændrɪəl/ produced in response to the target word "earth" displays no obvious relationship in either meaning or phonology to its target, making the underlying generation mechanisms for this error less apparent.

1.4 *Word processing*

1.4.1 Normal word processing

Analysing and measuring nonwords by their phonological quality and relation to their target has been most commonly implemented in picture naming paradigms, with nonword error responses analysed in relation to the cognitive-linguistic processes underpinning the task. Broadly, models of single word production, based on picture naming as the probe, incorporate three key processes. The first process is semantic, where a words meaningful representation is accessed. The second process involves the activation and accessing of the abstract 'word' representation, where an abstract and unitary representation of the word is stored, and the third process is phonological, where the broad phoneme representation corresponding to a word is accessed (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Goldrick & Blumstein, 2006; Levelt, Roelofs, & Meyer, 1999). There are numerous different accounts describing further intricacies of the word production process and how cognitive stages exist and interact with one another, and the lack of consistency across architectures and accounts confounds integration of behavioural patterns within cognitive-linguistic theory. Furthermore, these accounts become increasingly complex as additional production tasks, such as reading aloud and auditory repetition, are added into the frameworks. One of the major aims of this thesis is to consider Jargon production across naming, reading and repetition and to consider the observed patterns in relation to cognitive frameworks to derive insights into the Jargon impairment. To this end, this thesis adopts a hybrid theoretical position, integrating core components of contemporary models of single word production, including frameworks accounting for auditory repetition and word reading.

1.4.2 Core components of picture naming

When naming a picture, the first cognitive process needed is image perception, which requires visual-spatial perception and processing. The visual representation then activates the corresponding conceptual-semantic representation – the meaningful idea of the word or object. The conceptual-semantic activation then transfers to a word representation. In existing models of word processing, this level is described as comprising a single representation for each word, however the Dell et al., (1997) architecture proposes interactive bi-directional connections to and from this representation, meaning access and activation is not necessarily discrete. This word level activation is then transferred to the corresponding sound segments, where the most activated units are selected for further processing (Dell et al., 1997; Levelt et al., 1999; Roelofs, 1997). Further processing comprises selection of motor programmes and initiation of a motor plan (Roelofs, 1997; 2014). People with Jargon aphasia are often described as presenting with no significant motor deficits (Buckingham & Kertesz, 1974; Kinsbourne & Warrington, 1963; Olson, Romani, & Halloran, 2007). Where this has been evaluated experimentally, people with Jargon aphasia do not demonstrate symptoms of a phonetic or motor deficit, in that there are no reports of phonetically complex syllables or phonemes being substituted for segments which are phonetically easier to articulate (Godbold, 2017; Olson, et al; 2007; 2015). The current thesis is concerned with exploring error patterns associated with lexical and phonological processing (see Figure 1.1); however, consideration will be paid to additional, possibly interacting processes, such as motor and monitoring mechanisms in the general discussion.

1.4.3 Reading and Repetition

Tasks of reading and repetition differ from picture naming in that they can benefit from additional surface level information, phonemes (sounds) and graphemes (letters), which can be used to support lexical and phonological processing (Coltheart, 1993; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Seidenberg & McClelland, 1989). A number of reading/repetition architectures have been proposed, which differ in their incorporation and reliance on surface level material to support word reading/repetition. One major viewpoint is that there exist two routes operating in parallel, with one route using the graphemes or phonemes to access a lexical representation of the target word and the other route converting the surface word phonemes/graphemes into their phonological representation for output. Information from both routes converges at phonological processing and then proceeds for phonetic and motor processing (Baron & Strawson, 1976; Coltheart, 1978; Coltheart et al., 1993; Patterson & Morton, 1985). By this theory, information from lexical and sub-lexical/nonlexical representations inform phonological encoding for production. Distributed processing models postulate three key processing components of semantics, phonology and orthography which are interactively connected and influence one another (Patterson et al., 1989; Plaut & Kello, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). These models postulate that both lexical (words) and nonlexical (nonwords) items are processed via orthography (written words) or phonology (spoken words) and that lexical effects emerge from interconnecting 'hidden' units which reflect learned connections between these sub-systems and semantics. The units are referred to as 'hidden' as they lack a specific functionality. By this account, lexical effects occur in repetition and reading as a product of the speakers learned experience, with lexical information emerging from the input string and its connections within the network.

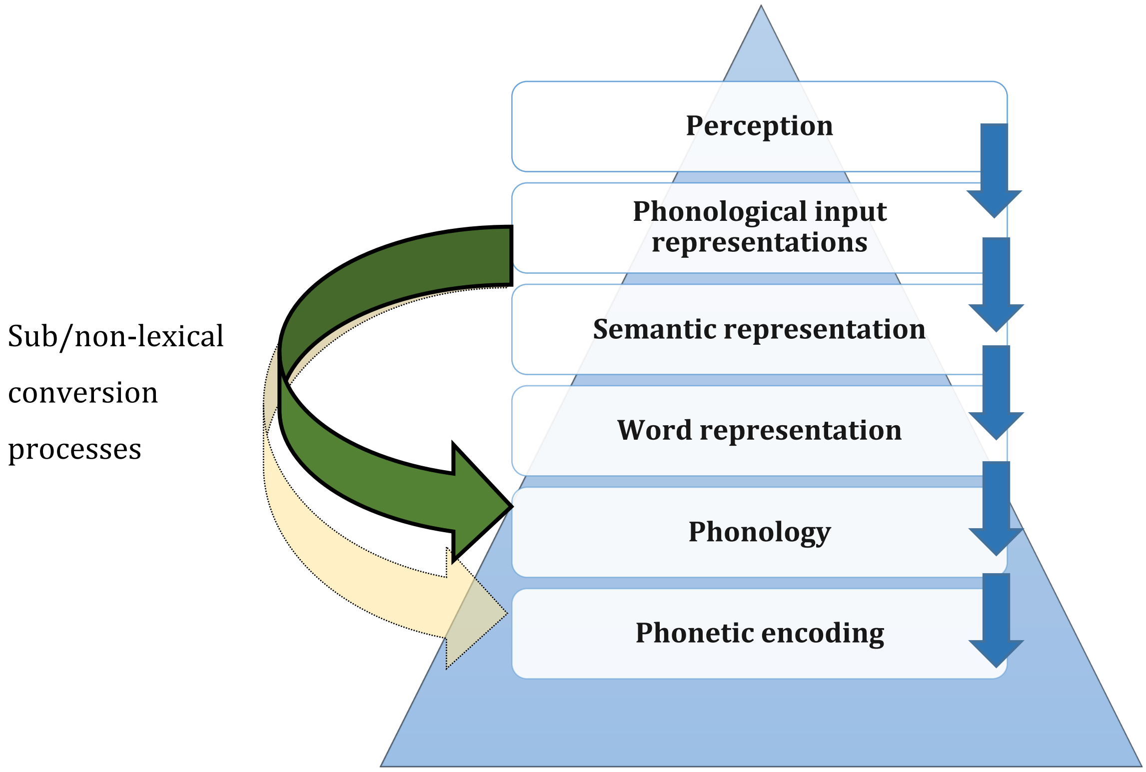


Figure 1.1: Diagram of the major stages of single word production. Blue arrow reflects information transfer. Green arrow reflects lexical processing in reading/repetition and yellow arrow reflects nonlexical input-output conversion process.

1.5 ***Theories of nonword production***

1.5.1 Overview of nonword theories

Analysis of nonword production patterns in Jargon aphasia have resulted in three key theoretical positions. One of these was derived from the observation that neologistic production often evolves into anomia, suggesting that nonwords mask underlying word finding deficits which improve over the course of recovery (Buckingham, 1977; Butterworth et al., 1989). By this theory, nonwords occur through phonological reconstruction which happens when access to a word representation fails and phonological selection is not based on a target phonological representation. This generates nonwords with low target overlap (e.g. nonword /bændrɪəl/ produced in response to the target word "earth") and is often referred to as **Anomia theory**. Another major theory posits phonological selection error during phoneme processing, following correct retrieval of the target word representation (Kertesz & Benson, 1970). This theory accounts for nonwords which are closely related to their target word (e.g. /witwim/ for the target word "witness") in that mild phonological processing disruption causing some segment selection error, whilst nonwords which have lower target overlap (e.g. /bændrɪəl/ produced to the target word "earth") occur from the same mechanism but when more significant disruption to phonological segment selection has occurred. This theory is often referred to as **Conduction theory** and was originally based on word production accounts which posited a post-lexical phonological level where selection and processing was disrupted. By this account, nonword errors arise from a single phonological deficit which distorts target phonological representations to varying degrees, with severe nonword errors (e.g. /bændrɪəl/ for "earth") and mild nonword errors (e.g. /wɪtwɪm/ for "witness") falling at the extreme ends of a single continuum of phonological disruption.

Recent computational evaluations of Jargon error mechanisms have evaluated nonword error patterns in Jargon aphasia within lexical access frameworks, considering whether nonword errors occur from a *word* selection deficit or a *phonological* selection deficit as part of lexical selection. These lexical frameworks often have three layers of representations: a semantic level, a word level and a phonological level. Semantic units are connected to word units and word units are connected to phoneme units, with activation transferred across this network bi-directionally. Units which are the most active are selected for further processing and, ultimately, production. By this account, nonword errors arise when connections between a word representation and its corresponding phonological segments are not successfully transferring activation, allowing non-target phonology to compete and intrude (Dell et al., 1997; Foygel & Dell, 2000; Martin & Dell, 2007), suggesting nonwords are underpinned by a phonological processing deficit as part of lexical retrieval. This theoretical position is referred to as the **Lexical-phonological theory**, as it considers nonword error mechanisms as part of phonological selection within lexical processing. By this description, a lexical-phonological representation is the phonological code stored within the lexical representation of a word.

1.5.1.1 Conduction theory

Conduction theory suggests that a correctly retrieved target item is affected by 'phonemic distortions' (Kertesz & Benson, 1970, p.385). Original descriptions of this theory implied that the deficit was post-lexical in nature, suggesting that a correctly selected phonological string is distorted during post-lexical phonological processing and aligning with the error process associated with conduction aphasia more generally (Buckingham, 1977; Kertesz & Benson, 1970; see Figure 1.2). Kertesz and Benson (1970) suggested that this conduction deficit could generate both closely related nonword errors and nonword errors with extremely low overlap, with the latter occurring from significant disruption during phonemic processing and the former occurring with relatively mild disruption. A number of Jargon aphasia case studies present evidence consistent with this hypothesis (Hillis, Boatman, Hart, & Gordon, 1999; O'Connell, 1981; Olson et al., 2007), suggesting that nonword errors in Jargon aphasia arise from a single phonological mechanism. In more recent reports considering nonword error mechanisms in Jargon aphasia, the conduction account has come to represent an impairment in phonological activation and processing more broadly encompassing phonological processing (Buckingham, 1977; Dell et al., 1997; Robson, Pring, Marshall, & Chiat, 2003).

Buckingham and Kertesz (1976) described the nonword errors produced by Jargon participant BF to evaluate whether his productions confirmed the conduction theory hypothesis. He produced a number of nonword errors with high phonological accuracy suggesting mild disruption during phonological processing had generated some of the nonwords he had produced. However, BF also produced a significant number of errors with low phonological overlap, with very few errors observed in between these two nonword groupings. The error pattern produced by BF suggested there exists two populations of nonwords errors, with one grouping of nonwords – the higher accuracy productions – conforming to the conduction hypothesis and the lower accuracy grouping of nonwords appearing to lack any target constraint and conforming to anomia theory. Buckingham and Kertesz (1976) suggest that the scarcity of nonword errors observed with mediocre phonological accuracy challenge the single phonological hypothesis, which should generate nonwords containing moderate phonological accuracy alongside nonwords with high/low accuracy nonwords. The error patterns exhibited by participant BF suggest that there exist separate nonword generation mechanisms which generate errors consistent with the conduction and anomia hypotheses.

Conduction Theory suggests nonwords occur when the correctly identified word form is disrupted during phonological processing.

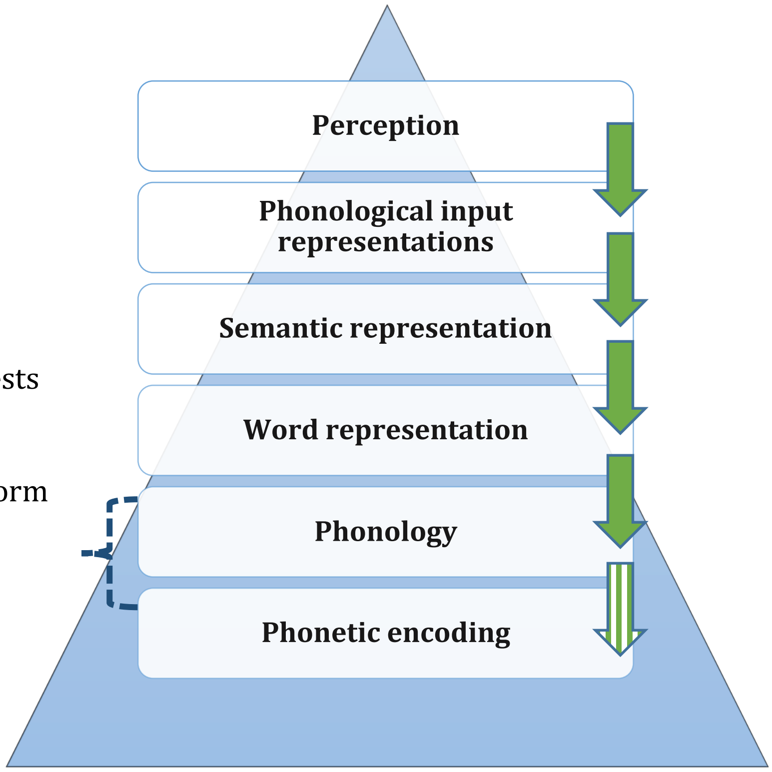


Figure 1.2: Conduction theory positioned within a single word production framework. Arrows indicate information transfer across layers. Green indicates target information processing; dashes indicate partially successful target processing.

1.5.1.2 Anomia theory

The Anomia hypothesis states that remote nonword errors, e.g. /bændrɪəl/ for "earth", are underpinned by a word finding deficit, whereby the appropriate phonological information cannot be retrieved or accessed (see Figure 1.3). With no target form available, phonological constructions operates without reference to the target word form, meaning phonological selection is not constrained by the target phonological segments. Butterworth (1979) presents an analysis of a Jargon aphasia participant, KC, and his phonological production in support of anomia theory. Within KC's nonwords, the word initial phoneme frequency did not adhere to the typical statistical constraints of the learned phonological system in English, which was interpreted as reflecting a lack of lexical constraint over his nonword production. In a separate report of KC, the length of pause prior to nonword production was a measured to reflect word search time, under the hypothesis that nonwords arising from anomia theory would follow longer pauses than nonwords generated during phonological segment selection error (Butterworth, Swallow, & Grimston, 1981). Additionally, KC's hand gestures were analysed for their completeness, and incomplete hand gestures were interpreted as reflecting failed lexical access. Longer pauses and incomplete hand gestures were found to coincide with production of low accuracy nonwords, whereas nonwords which displayed higher phonological accuracy had shorter reaction times and were associated with more complete gesture action. These results led Butterworth to propose that severe nonwords embodied randomly selected phonology which was concatenated for production when lexical access had failed. The nonword errors associated with this mechanism lacked lexical constraint and therefore did not necessarily conform to typical phonotactic patterns observed in lexical items in English. This pattern was interpreted as evidence supporting anomia theory.

This theory attracted criticism due to the proposed acquisition of novel word production mechanism becoming operational after brain damage (Marshall, 2006). However, a number of case reports document evidence which align with this hypothesis. For example, Kohn et al. (1996) analysed the production and recovery of four participants who had Jargon aphasia and high rates of neologistic production. The phonological content of the speech of two of the participants became increasingly accurate over the course of recovery; however, the remaining two participants continued to produce nonwords with low phonological accuracy. The latter two participants also produced perseveration, suggesting that they constructed nonwords with heavy reliance on previously used material. Kohn et al. (1996) suggested that these dissociating patterns reflect two different nonword mechanisms. The first pattern, which is associated with the recovering individuals, suggests that Jargon is a symptom of word access impairment which improves over the course of recovery. The second pattern, which is associated with a static and severe Jargon production, is associated with a loss of lexical-phonological representations. Where nodes and representations themselves are lost, production cannot improve with time, and so this state of Jargon, which Kohn refers to as anomia, continues throughout the course of recovery.

Kohn and Smith (1994) provide further detail on how anomia might come to fruition in Jargon production in their case report of VN. They argue that an impaired ability to locate a lexical representation would cause phonological production to comprise of randomly selected phonological segments, aligning with Butterworth's anomia account of Jargon. By this account, word representations are available, but the person with Jargon aphasia has an impaired ability to find the target representation at the right time, and will use alternate word representations to supplement phonological encoding. However, the error analysis demonstrated that VN's phonological production tended to include approximately seventy percent target word phonemes and that this proportion increased over a five-month period. This suggests that target word representations were being partially accessed, indicating that target word representations were available to VN and that they became increasingly easier for VN to access more completely as recovery progressed. This error profile implies that VN had a deficit in fully activating phonological information from word representations, suggesting partial retrieval of lexical and phonological target information, conforming to the lexical-phonological impairment outlined above.

Anomia Theory suggests nonwords occur when access to target word phonology has failed – word units may be lost or disconnected from phonology.

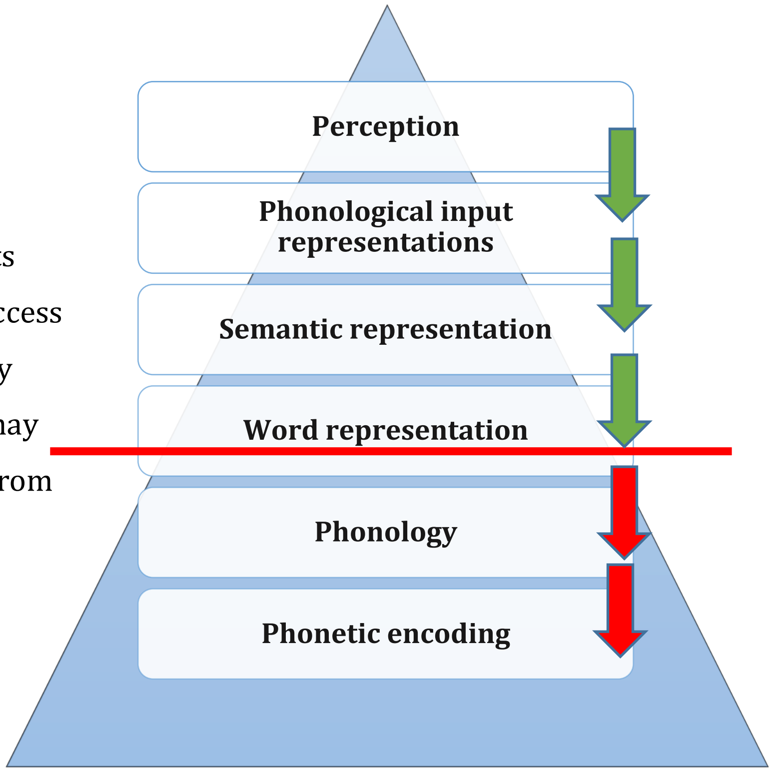


Figure 1.3: Anomia theory situated within a single word production framework. Arrows indicate information transfer across layers. Green indicates target information processing, dashes indicate partial success of target word processing, red indicates non-target information.

1.5.1.3 Lexical-phonological impairment

The partial retrieval of lexical-phonological representations (see Figure 1.4) has been explored in relation to nonword error production within frameworks of two-step lexical access in word production (Dell et al., 1997; Foygel & Dell, 2000; Nozari, Kittredge, Dell, & Schwartz, 2010; Schwartz, Dell, Martin, Gahl, & Sobel, 2006). These frameworks have a semantic, a word, and a phoneme layer, with each layer connected to neighboring layers. By this account, nonword errors arise when connections between a word representation and its corresponding phonological segments are not successfully communicating, allowing non-target phonology to compete and intrude. This lexical-phonological impairment theory has been simulated, using computational models, by altering connection weights within the word processing levels and between the word and phonological stages to manipulate the degree of activation that is transferred across the levels. Dell at al. (1997) used this computational simulation to model the nonword error patterns of 21 fluent aphasic participants, demonstrating that nonwords occur when activation is not sufficiently transferred across the network to facilitate accurate phoneme selection, indicating that nonword errors arise from a lexical-phonological locus. Such architectures have been used to simulate aphasic production and have demonstrated that nonword errors can be accounted for by a lack of activation transferring from the word level to the subsequent phonological nodes (Dell et al, 1997; Nozari et al., 2010), demonstrating that the source of nonword errors is partial activation of lexical-phonological information. More remote nonword errors (e.g. /bændrɪəl/ for "earth") occur when very limited activation is transferred from the word to the phonological layer, which allows for significant influence of intrinsic noise over production, whereas errors that more obviously embody the target arise when greater amounts of activation are transferred into phonology from the word representation layer.

Schwartz, Wilshire, Gagnon & Polanksy (2004) provide further support for this claim with their analysis of 457 nonword errors from 18 participants with fluent aphasia. They explored the phonological accuracy of nonwords and tested whether nonword phonological content was distributed according to a single error mechanism – indicated by a continuous distribution, whereby the majority of errors comprise intermediate levels of target phonology, with fewer errors observed at the severe ends of the spectrum when lexical-phonological activation has almost entirely failed or succeeded. Results demonstrated that error quality pertained to a normal distribution and supported a single source of error, which Schwartz et al. (2004) interpret as supporting the single – lexical-phonological – source of Jargon error. There exist a number of Jargon case studies that provide further evidence supporting a phonological mechanism of error. Robson, Marshall, Pring and Shallice (2003) present individual LT who consistently produced nonwords with a greater than chance overlap, indicating that nonwords were constructed with reference to target lexical-phonological information. Olson, Romani and Halloran (2007) report on individual VR who produces similar patterns of error across different production tasks, indicating a single source underpins her errors. Their case series (Olson, Halloran, & Romani, 2015) of an additional two Jargon participants demonstrated that nonword accuracy was normally distributed and that accuracy was greater than a chance prediction, providing further evidence that a single source underlies their nonword production.

Lexical-phonological Theory implicates partially activated target phonological segments from the abstract word representation.

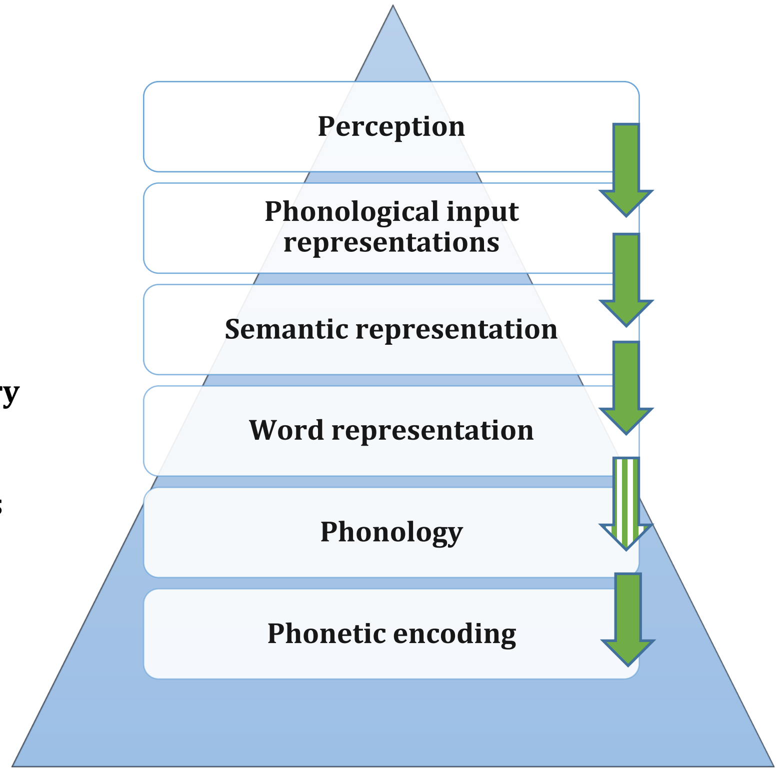


Figure 1.4: Lexical-phonological theory positioned within a single word production framework. Arrows indicate information transfer across layers. Green indicates target information processing; dashes indicate partial information retrieval.

1.5.1.4 Integrating anomia, conduction and lexical-phonological hypotheses.

There is significant overlap between these theoretical positions, in particular the Lexical-phonological theory and the Conduction theory, as both suggest impaired phonological processing as causal. The Lexical-phonological account suggests that the activation and retrieval of the phonological code – the segments which make up the phonological form of the target word – is only partially successful. The Conduction account traditionally implicates a level of phonological processing associated with transmission of the selected segments for further processing, implying that correct selection of the phonological code as part of lexical retrieval had already taken place, and that the target form is disrupted by phonemic transformation during further phonological encoding. Kertesz and Benson (1970), who proposed the Conduction hypothesis, suggested that phonemic transformation occurred as a result of arcuate fasciculus damage which resulted in the selected word form being disrupted as it was further encoded for production, implying that the errors produced by people with Jargon aphasia are not unlike those produced by people with Conduction aphasia. However, recent investigations considering these hypotheses adopt a broader theoretical position regarding phonological processing impairment associated with Jargon aphasia, asking whether a word finding deficit, or a phonological deficit best explain the error profile observed in Jargon aphasia.

The word finding position aligns closely with Anomia theory and is usually considered as a complete failure in accessing the word representation, meaning phonological construction is not constrained by the target word form. This can happen when a word representation is damaged or its connections to phonological units are severed (Kohn et al., 1996). The phonological position considers whether nonword errors reflect partially retrieved target phonological information. For example, Dell et al., (1997) demonstrated that nonword errors occurred when phonological units were insufficiently activated from the earlier word level layer, suggesting that poor activation of the lexical-phonological code underpinned Jargon errors. Many of the existing studies considering nonword mechanisms adopt a position similar to that taken in Dell et al., (1997), examining whether a single phonological deficit can best explain the error pattern observed or whether an additional anomic-like impairment provides a more comprehensive explanation (Olson et al., 2007; 2015; Robson et al., 2003; Schwartz et al., 2004). A number of these studies provide further analyses exploring whether the phonological impairment aligns with a lexical or a post-lexical phonological mechanism. Nozari et al. (2010) and Olson et al. (2015) demonstrate that nonwords are influenced by lexical frequency, a factor which is considered to exert a strong influence over transfer of information into phonological selection. Where activation between these levels is weakened, effects of frequency are expected to emerge because stronger patterns of activation are more likely to succeed in activating the corresponding segments. Kohn and Smith (1994) and Goldrick and Rapp (2007) suggest that errors which maintain the onset of the target word are more consistent with a post-lexical phonological process which organises phonological material from left to right. Errors produced by aphasia participants in these studies demonstrate phoneme position-specific effects, with errors increasingly likely towards the end of the word which is consistent with a post-lexical process with encodes the phonological string which was retrieved from the lexicon.

This thesis adopts the position which is considered in the majority of recent research reports exploring nonword error patterns in Jargon aphasia, as identified in the literature review. Two theoretical positions are considered: (1) Anomia theory, considered to reflect failed access of the target word form followed by phonological construction which is not target constrained; and (2) phonological theory, which is considered as insufficient activation of target phonological information. This thesis does not explicitly consider whether this phonological impairment exists inside or outside of lexical processing; however, this theme is revisited in the general discussion.

1.5.2 Nonword errors in word repetition

Sources of nonword errors in tasks aside from picture naming have been evaluated most comprehensively in computational modelling accounts exploring the lexical-phonological hypothesis. Naming accounts have been extended to word repetition by addition of a nonlexical route which maps incoming sounds directly to output phonological segments for selection. This nonlexical route can accomplish word repetition independently, or alternatively, this route can be recruited alongside the lexical-phonological avenue to collaboratively support phonological selection. In aphasia, nonword error patterns from tasks of picture naming and repetition have been used to determine which of these route processing options is most accountable for error patterns. This has been tested in a number of studies (Baron, Richard Hanley, Dell, & Kay, 2008; Dell, Martin, & Schwartz, 2007; Dell et al., 1997; Hanley, Kay, & Edwards, 2002; Nozari & Dell, 2013; Nozari et al., 2010) which have demonstrated that models including a nonlexical mapping route provide the best account of nonword errors patterns in repetition, as oppose to a singular lexical route model, and confirms that patients with aphasia accomplish repetition via both lexical and sub-lexical/nonlexical processes. This body of work has also demonstrated that, for the most part, repetition will most likely be accomplished via the lexical route, because using an existing and established route following initial word recognition is the most efficient processing option. When ability to recognize and comprehend an auditory word is compromised – as it is in most individuals with Jargon aphasia – processing will be attempted with greater reliance on the nonlexical pathway to facilitate phonological processing and production accuracy (Nozari & Dell, 2013). If this route does not yield useful or accessible information, as is the case when Jargon aphasia co-occurs with Wernicke's aphasia and auditory-phonological processing is compromised, processing will revert back to the more frequently used lexical route.

1.5.3 Nonword errors in reading aloud

There is less exploration of nonword error patterns produced in Jargon aphasia reading aloud. Published accounts comprise single case studies or small case series that either qualitatively explore the nature of errors across different production tasks or analyse the quality of nonword accuracy distributions to determine whether nonword errors embody a single deficit at the level of phonological segment selection, or whether errors reflect contributions from lexical (word selection) and phonological (sound selection) components. For example, Olson et al., (2015) analysed the phonological accuracy of nonwords in repetition, reading and naming. Olson et al., observed lower phonological overlap in naming, indicating that repetition and reading benefited from the nonlexical information (input phonemes and graphemes). Olson et al., (2015) also observed effects of psycholinguistic variables frequency and concreteness within the production patterns of participants with Jargon aphasia, which are associated with lexical selection. Taken together, this suggests that reading (and repetition) are accomplished with the use of lexical and nonlexical information, and that nonlexical information can be used to supplement phonological processing for production. A number of other case studies report participants who perform poorly on picture naming in comparison to reading and/or repetition, further supporting this hypothesis (Corbett et al., 2008; Hirsh, 1998; Moses, Nickels, & Sheard, 2004a). The neurological and behavioural profile of Jargon aphasia is associated with deficient auditory-perception and processing skill but relatively persevered visual processing suggesting that nonlexical processing in repetition should be poorer than nonlexical processing in reading and implying that phonological accuracy in reading aloud should be better than phonological accuracy in auditory repetition tasks. However, this pattern does not clearly emerge. For example, participant KVH, reported by Moses et al. (2004a) is significantly more errorful in reading and naming in comparison to auditory repetition, despite presenting with

Conduction aphasia and phonological processing impairment as identified by the Western Aphasia Battery.

Together, these dissociating patterns demonstrate that no one theoretical position can comprehensively account for the nonword production patterns observed in Jargon reading and repetition. The relationship between lexical and nonlexical processing in repetition and reading appears to conform, partly, to that in healthy speakers, with some evidence suggesting that nonlexical processing facilitates production in Jargon aphasia (Olson et al., 2015). Modelling data suggest that the relative contribution of the two pathways relates to the degree of damage; however, case-studies reports of Jargon repetition and reading are few, and production patterns from individual cases is not always consistent with this pattern. The experimental chapters of this thesis examine Jargon aphasia error production on tasks of repetition and reading, with Chapters 3 and 4 exploring how lexical processing and selection mechanisms impact on Jargon production, in relation to theoretical positions postulating word and phonological selection mechanisms.

1.6 ***Perseveration***

1.6.1 Perseveration background

An additional potential source of non-target phonology in Jargon aphasia is perseveration – the erroneous repeated use of phoneme segments across production trials. There exist a small number of early case studies that document verbal and gross motor manifestations of perseveration, which define the phenomenon as unintentional error in action (Hudson, 1968; Pietro & Rigrodsky, 1986; Sandson & Albert, 1984). Sandson and Albert (1984) provide a description of three different varieties of the behaviour: stuck in set, continuous, and recurrent. The stuck in set form of perseveration is attributed to executive function disruption and described as continuous topic or framework maintenance. Sandson and Albert (1984) demonstrate this using participant JK who erroneously continued with line bisection during a later task of trail making. This perseverative behaviour was also observed in the verbal modality when JK was unable to transition from a forward digit span task to a backwards version of the task. Continuous perseveration is described as uninterrupted continued behaviour and illustrated by Sandson and Albert (1984) using participant who has Parkinson's disease, who repeatedly adds on looped shapes when attempting to draw a three looped figure. The final category proposed by Sandson and Albert (1984), and described most frequently in relation to aphasia, is recurrent perseveration; *"the unintentional repetition of a previous response to a subsequent stimulus"*. (Sandson & Albert, 1984, p1). Sandson and Albert (1984) give an example of a non-verbal recurrent perseveration as erroneous digit writing when populating a clock face with numbers. Verbal recurrent perseverations often manifest as repeated productions of a single word produced to subsequent, different, target items. Recurrent perseveration may also manifest as single, erroneous, phonemes being reproduced across subsequent production trials (Moses, Nickels, & Sheard, 2007).

Within the recurrent sub-type, perseverations are divided into two major types: a total or whole word perseveration. A total perseveration occurs when a complete word or nonword item is unintentionally repeated in full, whereas a partial or blended perseveration occurs when part of a previously produced utterance is erroneously repeated, such as phoneme segments erroneously reproduced across subsequent trials. Santo Pietro and Rigrodsky (1986) provide a detailed commentary regarding this division, analysing the perseverative errors produced by 34 people with aphasia on a task of single word picture naming to demonstrate perseveration subtypes. Santo Pietro and Rigrodsky (1986) explain that whole word perseverations can either be semantically mediated, such reproducing the response 'apple' when presented with any food item picture, or phonologically prompted, such as reproducing a whole response that started with a specific phoneme when presented with a new target word which shares the word initial phoneme. The most commonly observed perseveration pattern, termed 'Phonemic carry-over' by Santo Pietro and Rigrodsky, was the partial reuse of an earlier produced response mixed with new phonological material. This is commonly referred to as a blended perseveration. It was also observed that perseverations often occur in series, whereby repeated whole words or parts of words are consistently reproduced to consecutive targets. There exist very few recent documentations of perseverative behaviour in such a descriptive manner; however, existing case reports of perseveration in aphasia conform to these patterns and trends (Hirsh, 1998; Moses et al., 2007).

Perseveration is observed in various types of aphasia, including Jargon. This suggests an underlying mechanism that is common across aphasia subtypes (Martin & Dell, 2007). Originally, deficient inhibition was hypothesised to underpin perseveration. Santo Pietro and Rigrodsky (1986) described this as an inefficient decay of a working memory trace, which could either be of a whole word or of component parts of a word such as a phoneme, and maintenance of this memory trace causes involuntary reproduction when subsequent target items are processed. Buckingham, Avakain Whitaker and Whitaker (1978) provide a more detailed description of the blended perseverations observed in three people with Jargon aphasia, referring to alliteration, the repetition of consonants, and assonance, repeated vocalic segments, as specific hallmarks of Jargon aphasia. Buckingham et al., (1978) propose that perseveration occurs when target word information has not been sufficiently retrieved. Differentiating between these two theoretical viewpoints – poor activation of targets versus inefficient decaying of previous productions – is controversial and this remains the basis for much of the recent research examining verbal perseverations.

1.6.2 Failure to activate

1.6.2.1 Healthy adult population

The majority of recent work exploring verbal perseverations has concluded that poor activation of target information allows for recently used words or phonological segments – that will have higher than normal levels of activation due to their recent useage – to override deficiently activated target units (Cohen & Dehaene, 1998; Fischer-Baum & Rapp, 2012; Martin & Dell, 2007; Moses et al., 2004a; 2007). Attempts to elicit perseverations from the neurologically healthy population have made use of intrinsic psycholinguistic word properties, such as word frequency, to test this hypothesis, under the assumption that words which are less frequently used take longer to produce because they reside with lower levels of neural activation. This lower level of resting activation means that selection and production of these words requires greater processing effort, in the form of incoming activation. Words which are more frequently used tend to be produced more quickly and are associated with less error, indicating that less activation is required for their successful selection. Vitkovitch and Humphreys (1991) adapted this theory and demonstrated that neurologically healthy people were more likely to produce a perseveration when responding to a lower frequency target word under response deadline conditions. Moses, Nickels, and Sheard (2004b) made use of differing task demands between naming and reading to test whether compromised processing capacity in a certain domain or processing component resulted in increased perseveration, expecting picture naming to generate more perseverations due to increased lexical-semantic requirements in comparison to word reading. Their results supported this hypothesis with significantly more perseverative errors observed in picture naming than in word reading. Moses and colleagues interpret this as supporting an account of perseveration that postulates compromised processing capacity as causal. By this account, tasks which require greater amounts of activation or effort are more likely to be contaminated by responses from previous trials because target activation is more likely to be compromised, meaning the prior unit is easier to process and is more likely to outcompete the current target. Computational modelling studies which simulate perseveration (Dell, 1986, 1990; Schwartz, Saffran, Bloch, & Dell, 1994) have demonstrated that reduced connection strength between word and phoneme levels – reflecting lower activation transfer and reduced time for activation spread - emulate the error pattern observed in healthy speakers.

1.6.2.2 Aphasia population

This computational modelling approach has been extended to patients with aphasia and perseveration by Martin and Dell (2007). They report on the error patterns of 94 individuals with aphasia; the largest scale study of aphasic perseveration to date. The methodology adheres to that in Schwartz et al. (2006), with connection weights between layers altered to simulate reduced activation between the semantic, word, and phonological layers of the lexical network. Weakly activated semantic representations would address a word representation that, in turn, would receive insufficient activation and limit the activation transfer between subsequent word and phonological layers. Martin and Dell (2007) demonstrated that altering the amount of connection weight between these layers successfully simulated patient perseveration patterns and compromising activation at particular points of the network made certain types of error more probable. For example, reduced activation of word units was more likely to generate whole word perseverations, whereas reduced activation from the word to the phoneme layer was more likely to generate blended or phonological perseverations. The weaker or lesser this activation, the more likely phoneme perseveration errors became, indicating a continuity between phonological error and perseveration and implying that perseveration arises from the same error mechanism as non-perseverative errors. Similar trends are reported in Dell et al. (1997), where more severe aphasia presentation is associated with greater amounts of nonword error and preservation. However, participants with Jargon-like production impairments are underrepresented in these studies, limiting the applicability of these findings to Jargon aphasia. A small number of studies report similar trends in people with more severe, Jargon-like impairments (Helm-Estabrooks, Ramage, Bayles, & Cruz, 1998; Kohn et al., 1996; Pilkington et al., 2017). A small sub-set of participants reported in Kohn et al., (1996) and Pilkington et al., (2017) produce perseverative patterns that contradict this trend, producing high rates of perseverative errors alongside very few non-perseverative phoneme errors. This is challenging to reconcile within the failure to activate hypothesis of perseveration which suggests a common error mechanism underpinning both perseverative and non-perseverative error and implies similar numbers of both error types should be observed.

One of the biggest challenges and limitations to examining perseveration is the lack of methods existing to measure all aspects of the behaviour. Cohen and Dehaene (1998) present a sophisticated method for quantifying perseveration which they implement to quantify the phoneme errors produced by a participant with Wernicke's aphasia. Their method counts the occurrence of individual error phonemes which have been produced previously on earlier trials, recording the number of intervening responses between an observed phoneme perseveration and its most recent prior production, which Cohen and Dehaene refer to as the 'lag'. The lag is used to index the duration of phoneme segment activation post-production and to indicate how long a segment remains a privileged candidate for selection. Cohen and Dehaene (1998) conclude that a phoneme segment maintains heightened activation up to three trials post production and suggest that this aligns with the failed activation account, since sources of phoneme perseverations are restricted to trials which are temporally close. This conclusion is based on decay rates associated with residual activation, or post production decay, which Cohen and Dehaene (1998) derive based on studies of priming effects. Deficient activation would only give rise to phoneme perseverations that are temporally close, i.e. within 3 production trials to their source. Phoneme perseverations that occur at a lag greater than 3 cannot be accounted for within the failed activation hypothesis because residual activation does not persistent for more than 3 subsequent trials. Cohen & Dehaene (1998) suggest that inhibitory issues may explain the more distant phoneme perseverations that they observe, produced by the participants with Wernicke's aphasia and Jargon production.

Fischer-Baum and Rapp (2012) discuss the separation of these two, possibly independent, perseveration patterns in a group of people with acquired dysgraphia. They suggest that a sole deficit in inhibition would only generate perseveration errors and that there should be no relationship between rates of perseveration and other, non-perseverative errors if the inhibition deficit underpins all perseveration. On the contrary, deficient activation would allow for both perseverative and non-perseverative errors with the latter arising from competition or intrinsic noise within the language network and the former arising when residual activation is greater than the noise/alternate segment competition, and a clear relationship between the rates of these two types of error should be observed. Fischer-Baum and Rapp (2012) observed strong relationships between perseverative and non-perseverative grapheme errors, suggesting a common source underpinned both types of errors and supporting the deficient activation account. Further support for this account is reported in case studies by Eaton, Marshall and Pring (2010) and Moses et al. (2004a), who quantified the temporal course of phoneme perseverations, demonstrating that perseverations tended to occur at short lags, suggesting residual activation and deficient activation underpin phoneme perseveration. However, both of these studies also demonstrated that, for the participants reported in these case studies, specific phoneme patterns were preferred, and that certain segments or consonants appeared more often than expected in English. These idiosyncratic production patterns were upheld across different testing days, demonstrating that specific phonological segments dominate production, independent of the phonological context in which production has taken place.

This form of production is referred to as default or idiosyncratic and was originally proposed to occur when activation was deficient such that no target phonemes or lexical items were sufficiently activated, meaning whole strings of phonemes would be assembled and produced dependent on within system activation patterns (Butterworth, 1979). The phonemic production patterns observed in some people with Jargon support this hypothesis, with phoneme frequency distributions demonstrated as atypical or skewed towards specific segments or phoneme combinations (Eaton et al., 2010; Moses et al., 2004a). This pattern is explored in more detail in a case study by Robson et al. (2003) who derived a word set which had atypical consonant frequency distributions and used this word list to test whether phonological error production in Jargon aphasia exhibited the typical frequency effect, indicated by lower frequency phonemes replaced by higher frequency segments. The phonological frequency pattern observed within nonword responses indicated that high frequency consonants were used often but not necessarily accurately, whereas lower frequency segments were used less often but more precisely. This suggests that higher frequency segments are utilised in Jargon to supplement phonological construction when target phonological activation is poor.

1.6.2.3 Stimulus factors – intrinsic manipulations

Exploration of the failed activation hypothesis has focused specifically on stimulus factors that are known to modulate word activation levels. Word frequency is the most widely explored and documented psycholinguistic property and assumed to modulate activation levels in that more efficient production of higher frequency targets reflects lesser activatory input required for effective processing. On the contrary, words that are lower in frequency require more activation for processing as reflected by longer reaction times, and therefore perseveration will be more prevalent under such conditions under the failed activation account (Kittredge, Dell, Verkuilen, & Schwartz, 2008; Monsell, Doyle, & Haggard, 1989; Nickels & Howard, 1995). This hypothesis has been tested in numerous aphasia studies, and while a number of studies provide support for this theory (Gotts, della Rocchetta, & Cipolotti, 2002; Hirsh, 1998; Santo Pietro & Rigrodsky, 1986) there exist a similar number of cases documenting an absence of frequency effects (Ackerman & Ellis, 2007; Corbett et al., 2008; Halpern, 1965). These studies are not exclusive to fluent or Jargon aphasia and therefore do not directly indicate that deficient lexical activation is contributory in Jargon perseveration.

1.6.3 Failure to inhibit

Since the earliest reports of Jargon aphasia and perseveration, problems with inhibition have been suggested as causal (Papagno & Basso, 1996). Santo Pietro and Rigrodksy

(1986) described perseveration as being caused by *"retention of items in working memory"*, while Sandson and Albert (1984, p.717) explained *"the process deficit in recurrent perseveration involves a failure of the usual inhibition of memory traces".* These observations have stemmed from the copious output and fluent spoken production associated with Jargon aphasia, which is usually highly errorful but lacking in attempted self-corrections. Errors can have high phonological similarity, suggesting that people who perseverate may have an inability to alter their action or output (Brown, 1981; Buckingham et al., 1978). Both the activation and inhibition accounts suggest that, to use a specific unit or representation from the lexical network, it must be sufficiently activated past its baseline level of activation. Once used, this unit should then relapse back to its baseline resting state (residual activation) and allow for subsequent units to be processed (Dell, 1986). However, if the post-production decay process were damaged, such that activation decayed more slowly or not at all, previously used units would interfere with subsequent processing and impede selection of new words or segments (Fischer-Baum & Rapp, 2012). This theoretical account suggests that perseveration arises from a separate mechanism to nonword and phonological error in Jargon aphasia. Correlational analyses have been used to test this by exploring the relationship between the number of perseverative and non-perseverative errors, under the assumption that errors arising from a common source would be distributed similarly. Fischer-Baum and Rapp (2012) implement this analysis, identifying that all but one of their participants display correlations between the number of perseverative and non-perseverative graphemic errors. Martin and Dell (2007) also implement this approach in a study of 94 people who have aphasia, providing further evidence that perseverative and non-perseverative errors are related and co-occur, and Pilkington et al. (2017) find further evidence of this relationship. However, within both of these group studies outliers are evident, with a small number of participants producing high numbers of perseverative errors alongside very few non-perseverative errors, which is more consistent with an inhibition deficit which blocks new phonology or words from being encoded. It is also possible that very severe deficits in activating phonology would generate this pattern, where new information is so weakly encoded, that residual activation of prior units continues to dominate activation patterns. This form of persistent and severe failure to activate target information would also generate series of perseverations. Overall, the evidence examining perseverative mechanisms demonstrates that activatory and inhibitory processes are closely intertwined, and therefore are difficult to separate experimentally.

1.6.3.1 Stimulus factors – extrinsic manipulations

An alternative approach to examining perseveration mechanisms is to apply extrinsic manipulations to stimulus presentation and delivery which manipulate the time and completeness of inhibitory and activatory processing. Such manipulations have been implemented wit healthy speakers via the use of priming and application of response pressure. Priming involves repeated presentations of a test item, which increases the residual activation of this item and biases competition in favour of that prior item, making inhibitory processing more demanding. Time pressure restricts the amount of time allowed for encoding a new stimulus item, restricting activation of the current target. Applying these manipulations together minimises target activation and simultaneously increases residual activation, meaning the previous item is increasingly likely to outcompete the current target. In healthy speakers this manipulation increases error and perseveration (Moses et al., 2004b; Vitkovitch & Humphreys, 1991). However, this manipulation is limited in applicability to aphasia because application of time restrictions will likely increase the number of nonresponses produced, which reduces meaningful information and limits experimental analyses. To bias processing towards new target items and away from prior items, Corbett et al. (2008) used phonemic cueing, which was successful in minimising perseveration and increasing accuracy in their case study. Gotts et al. (2002) provided repetitions of a target word prior to production, demonstrating that repeated presentations improved production accuracy but also increased the likelihood that this word would be produced as a perseveration in subsequent trials.

Alternatively, encoding environments can be negatively influenced by limiting the amount of time a participant is given to respond to a word, constraining time for post-production decay from the earlier trial. For example, in their study of aphasic perseveration, Santo Pietro and Rigrodsky (1982) allocated either a 1 or 10 second interval in which to name a picture or a written word, demonstrating that the shorter response time (1 second) was associated with poorer production accuracy and more severe perseveration. Santo Pietro and Rigrodsky (1982) suggest that restricting the time allocated for activation to return to baseline in the 1 second response time condition increased the competition between previous and present items. A similar paradigm was implemented by Gotts et al. (2002); however, they failed to demonstrate that individual EB was more perseverative when response time was limited to one second in comparison to a longer interval of five seconds. On further examination of the perseverated errors, Gotts et al. (2002) demonstrated that the perseveration source was consistently identified across the two preceding trials and that this pattern was similar across the different time conditions. The time elapsed – 12 seconds across two intervening trials in the fast condition and 54 seconds across two intervening trials in the slow condition – did not influence the decrement in perseveration. Gotts et al. (2002) interpret that the inter-stimulus time interval alone does not directly impact on post-production inhibition, but rather, it is the number of intervening trials which impacts perseveration decrement. This pattern implies that active engagement in a task, in this case, processing of a target word, is more likely to influence inhibitory processing and minimise perseveration.

Only one study, published as a conference proceeding, has attempted to alter the severity of perseverations by manipulating the degree of task engagement when producing words. Kohen, Benetello, Guerrero, Kalinyak-Fliszar, and Martin (2012) asked people with aphasia to complete tasks of word repetition with either an unfilled 5 seconds interstimulus pause or a filled interstimulus task of reading aloud numbers 1 through to 5 together with the clinician. The unfilled pause condition requires less task switching because participants do not have to actively engage in different material in the interstimulus interval. The filled condition is associated with greater task demands as participants are required to actively engage in an alternative task in-between repeating target words. Kohen et al. (2012) compared rates of whole word perseverations produced under these two conditions. Out of the 14 people in the group, 11 people produced significantly more perseverations when alternating between word repetition and counting aloud, in comparison to the unfilled task. This pattern conflicts with the pattern reported in Gotts et al. (2002), as active task engagement increased the amount of perseveration observed. Kohen et al. (2012) suggested that the additional verbal task inserted between target words for repetition may have facilitated continued and heightened activation of the language system, causing activation at previous productions to be maintained via a spreading of activation. They also suggest that an alternative interpretation is that switching between the repetition and counting tasks may have restricted encoding of the subsequent target word, limiting activation.

1.6.4 Associative learning and perseveration

Many studies exploring perseveration in aphasia examine behaviour over a single testing session or within a short space of time. However, this approach fails to capture effects of automatic, associated learning which may arise from consistent perseveration and error production, which would alter the activation and decay weights associated with lexical and phonological representations. The theory of associative learning dictates that the brain and its networks continue to change as a result of the sensory inputs and outputs that it receives and actions (Gotts, 2016). By this learning principle, the occurrence of perseveration will increase the association between co-occurring phonological segments units and affect the relationship between within word neighbours, increasing the probability of future co-occurrence. Moses et al. (2004a) put forward this explanation to account for the phonological production patterns in their Jargon aphasia case study of KVH who produced whole word neologistic perseverations, suggesting that his chronic Jargon aphasia impairment may have significantly altered the frequency with which phonological segments reside within lexical representations. Overtime, this mechanism may lead to people with aphasia being overly reliant on a specific pool of phonological units. By this account, perseveration occurs when activation is substantially degraded, and processing is based on the most easily selectable items - the most frequently used phonemes. Persistent reuse or reliance on this subset of units will increase their frequency and lead to long term changes in the lexical-phonological network. Eaton et al. (2010) explored this hypothesis in two people with Jargon aphasia who produced high amounts of perseveration. They examined whether the patterns of phoneme use in spoken production conformed to the typical frequency distribution of English and whether there was any evidence of a link between ease of selection and perseveration. They demonstrated that the phoneme frequencies exhibited by both participants conformed to English norms, but that both participants demonstrated preferences for specific phonemes (i.e. they used certain segments more than expected) and that these were more likely to occur in perseverative responses than in non-perseverative responses. This pattern suggests that idiosyncratic production and perseveration may increase over the course of recovery, as erroneous production is continuously reinforced. However, there is inconclusive evidence of this, with two longitudinal studies focused on individuals with Jargon aphasia and perseveration identifying that nonwords and perseveration quantity decreased over the course of recovery (Eaton, Marshall, & Pring, 2011; Panzeri et al., 1987).

1.7 *Aims of the thesis*

The major aim of this thesis was to examine the cognitive-linguistic source(s) of Jargon aphasia nonword production and perseveration. This aim has been divided into four sub-aims, presented in the current thesis as four separate chapters. Further information about these aims are provided below, alongside a description of how they were achieved.

1.7.1 Chapter 2: Language and neurological profiles of Jargon aphasia.

A clear diagnostic criterion for Jargon aphasia is lacking. This limits clinical and theoretical work on the disorder and confounds interpretation across case studies and larger group reports. This thesis aims to provide further information on the neurological and linguistic profiles associated with Jargon aphasia, and to this end, Chapter 2 reports the lesion profiles for the 18 participants reported in the current thesis. This is presented alongside language profiling across key functions which are most commonly considered when identifying Jargon aphasia – auditory comprehension, repetition ability and fluency of spoken production, using the short form version of the Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2000).

1.7.2 Chapter 3: What can repetition, reading and naming tell us about Jargon aphasia?

The literature review identified that Jargon aphasia and nonword production has been explained by a single, phonological, source of error, or separate error sources affecting word selection and phonological selection separately. Chapter 3 aimed to examine the extent to which these theories can account for nonword production patterns in Jargon aphasia, using production tasks of naming, repetition and reading which engage lexical and phonological processing differently, with the naming weighing more heavily on lexical selection. If nonword errors occur secondary to phonological selection processes, error quantity and quality will be similar across word production tasks, since all production tasks require phonological encoding for production; however, if nonwords are associated with processes earlier than phonological encoding, for example, lexical and semantic selection, more errors would be expected in picture naming in comparison to tasks such as reading aloud and auditory repetition. This is because picture naming weighs more heavily on lexical selection in comparison to repetition and reading and placing greater processing requirements on a deficient process would elicit greater amounts of error. Results demonstrated greater numbers of errors were produced in tasks of repetition and reading in comparison to picture naming, suggesting that tasks which encourage focus on phonological material exacerbate Jargon and indicating phonological processing is core component of the disorder.

1.7.3 Chapter 4: When does lexical availability influence phonology? Evidence from Jargon reading and repetition.

Following on from Chapter 3, which suggested that the phonological theoretical position best accounts for the Jargon aphasia error profile, Chapter 4 explored whether the amount of lexical activation could be manipulated to alter the severity of phonological production in Jargon aphasia. To test this a psycholinguistic approach was adopted, with separate word sets characterised by high and low lexical availability developed for administration. Importantly, phonological processing demands of these target word sets were carefully matched. In line with the failure to activate account, it was hypothesised that word production would be improved when lexical availability was greater, since higher lexical availability is associated with greater resting level activation and would allow for easier access of target phonological segments. Across the group of ten people with Jargon aphasia, more nonword errors were produced when lexical availability was lower, however, for the most part, the quality of nonword errors was not different under the different lexical availability conditions. A subset of 4 participants produced fewer nonwords, greater phonological accuracy and less perseveration when processing words with greater lexical availability in auditory repetition. These participants presented with moderate phonological impairment suggesting that the activation hypothesis is upheld in people with moderate Jargon, however one participant with severe phonological impairment alongside strong semantic abilities demonstrated the hypothesized lexical effects, suggesting that particularly strong semantics can boost phonological processing in people with Jargon aphasia.

1.7.4 Chapter 5: Manipulating Phonological Encoding Conditions in Jargon Aphasia: Impact on Production Severity.

The literature review also identified that, complementary to the impoverished activation account, deficient inhibition or decay has been implicated in Jargon production. Although recent research has failed to find support for the faulty inhibition account, many studies have struggled to evaluate the contribution of inhibitory processes because of their close dependency with activatory mechanisms. Chapter 5 focuses on the time window immediately after word production to examine the contribution of inhibitory processes. No explicit time pressure was applied to the word encoding period, however single words were interleaved with non-language tasks which had varying cognitive demands, so as to evaluate the contribution of switching requirements and determine the optimum environment for phonological encoding. Single words were read aloud in four different conditions which each had a specific inter-stimulus interval; either a blank pause, a pattern-reversing checkerboard, a visual discrimination task and a standard delivery paradigm where all words were read aloud consecutively. Group level and case-series analyses were implemented, and it was expected that the additional time and task would facilitate improved Jargon production, creating bias away from previous production and indicating a role of inhibitory processes in Jargon aphasia. The group analyses demonstrated no consistent effects of trial types; however, the case-series analyses identified that trial manipulations influenced production for five of the eight participants, with the most consistent production benefits observed when a passive stimulation was administered in the form of a pattern-reversing checkerboard.

Chapter 2. Participants with Jargon aphasia

2.1 ***Presenting the participants***

This chapter will present behavioural and lesion profiles for the participants with Jargon aphasia included in this thesis. The first experimental chapter of this thesis (Chapter 3) was completed on pre-existing data which was collected by Holly Robson during the course of her PhD. The study design, data management, data processing, analysis and interpretation (including chapter/manuscript writing) was completed by Emma Pilkington. The remaining two experimental chapters of this thesis (Chapters 4 and 5) include a different group of Jargon participants who were tested by Emma Pilkington during the course of this PhD. The development, design and all stages of data management and interpretation were completed by Emma Pilkington. In each experimental chapter, participants are ordered by the severity of their production deficit, indexed by nonword error quantity on tasks of single word production. A number/letter code is used for participant identification which relates to the severity of their production deficit. For example, in Chapter 3, p1 produced the fewest nonword errors whereas p10 produced the most. This approach to participant ordering is adopted throughout all experimental chapters in this thesis. For the current chapter codes T1:T20 are used to identify each participant included in the current thesis. This order related to the order of presentation in each experimental chapter. By this approach, participants T1:T10 refers to participants presented in Chapter 3 (in severity order) and T11:T20 refers to participants presented in Chapters 4 and 5 (see Table 2.1) in severity order.

Table 2.1: Study participation and participant codes for participants with Jargon aphasia

Chapter 2	Chapter 3	Chapter 4	Chapter 5
T1	p1	x	x
T2	p2	x	x
T3	p3	x	x
T4	p4	x	x
T5	p5	x	x
T6	p6	x	x
T7	p7	x	x
T8	p8	x	x
T9	p9	x	x
T10	p10	x	x
T11	x	A	x
T12	x	B	1
T13	x	C	x
T14	x	D	2
T15	x	E	3
T16	x	F	4
T17	x	G	5
T18	x	H	6
T19	x	I	7
T20	x	J	8

2.2 ***Recruitment***

For completion of this thesis 10 people with Jargon-like production deficits were recruited; these participants are presented in Chapters 4 and 5 (see Table 2.1). These participants were identified for recruitment to this research study by Holly Robson during the course of her own research recruitment of participants with Wernicke's aphasia. Dr Robson facilitated successful recruitment by establishing a network with research nurses based in Berkshire, Buckinghamshire, Hampshire and Somerset. Recruitment was facilitated by using the mental capacity act to allow a consultee to refer participants at an early stage post stroke when they were still an in-patient but unable to provide informed consent. The participants presented in Chapter 3 were recruited to Holly Robson's PhD study in 2009. Speech and Language Therapy services in North West England were contacted directly by Holly Robson and Karen Sage to support the identification of people with Wernicke's aphasia. For this reason, the profiles of participants included in the current thesis mostly conform to a Wernicke's aphasia profile associated with Jargon production.

2.3 ***Recruitment challenges***

People with Jargon and Wernicke's aphasia presentations are challenging to recruit, primarily because of the low incidence of this form of stroke. In the UK it is estimated that approximately 250,000 people have aphasia (RCSLT, 2009). Kertesz and Sheppard (1981) estimate that, within the aphasia population, 30% of cases are classified as Wernicke's aphasia, transcortical sensory or conduction aphasia. However, as outlined in the introduction, this does not automatically capture all cases which qualify as Jargon aphasia. The posterior lesion location associated with Jargon aphasia indicates that most people with this form of production impairment will not have significant motor symptoms, which often means that they will require less physical care during hospital admission and, as a result, are more likely to be discharged early; this is another variable affecting recruitment of participants with Jargon aphasia. Furthermore, the nature of their communication profile – often impaired comprehension and considerable word production deficits – significantly impacts on functional communication, limiting participation in social communication groups. Social and community stroke support groups are another form of recruitment commonly adopted in research, thus, the under-representation of Wernicke's like participants in these settings is a further factor contributing to the challenge of recruiting people with Jargon aphasia.

2.4 ***Inclusion criteria***

Participants were identified as having Jargon aphasia according to their language profile on The Boston Diagnostic Aphasia Examination short form (BDAE; Goodglass, Kaplan & Barresi, 2001) and their single word production error profile – nonwords produced as the dominant error type. For the current thesis, the language profile associated with

Jargon aphasia was derived from existing reports of Jargon aphasia identified in the literature review (see Chapter 1). As reported in Chapter 1, the Jargon profile often includes impaired auditory comprehension (Alajouanine, 1956; Hillis, Boatman, Hart, & Gordon, 1999; Kertesz & Benson, 1970) which is associated with phonological processing impairment and poor auditory repetition (Buckingham & Kertesz, 1974; Butterworth, 1992; Robson, Grube, Lambon Ralph, Griffiths, & Sage, 2013; Robson, Keidel, Lambon Ralph, & Sage, 2012). Speech production in Jargon aphasia tends to be fluent (Brown, 1981; Kinsbourne & Warrington, 1963; Robinson, Butterworth, & Cipolotti, 2015) and the most consistent feature reported in phonological forms of Jargon aphasia is the production of large quantities of nonword error (Buckingham & Kertesz, 1976; Buckingham, 1981; Kohn, Smith, & Alexander, 1996; Moses, Nickels, & Sheard, 2004; Olson, Halloran, & Romani, 2015; Robson, Pring, Marshall, & Chiat, 2003). A number of case reports exercise flexibility in how these criteria are applied when identifying Jargon aphasia. For example, some reports include individuals with relatively preserved comprehension (Marshall, Robson, Pring, & Chiat, 1998) or repetition (Bose, 2013; Moses et al., 2004) and there is also variation reported in the fluency profiles of some cases (Bose, Höbler, & Saddy, 2019; Panzeri, Semenza, & Butterworth, 1987). As described in Chapter 1, the production of nonword errors is one of the most highly researched features of the disorder; therefore, high quantities of nonwords are essential for experimental analyses meaning less flexibility is exercised with this criterion. Having said this, there is no clear cut off for what proportion of output must be nonwords in order to indicate Jargon, and a number of case studies report variation in the quantity of nonwords within output of their Jargon participants (Buckingham & Kertesz, 1976; Eaton, Marshall, & Pring, 2011; Olson et al., 2015). These studies demonstrate a significant amount of variability within the Jargon aphasia profile, which may indicate a range of underlying cognitive mechanisms are associated with the disorder and the production of nonword errors.

The experimental chapters in this thesis (Chapters 3, 4 and 5) identified the presence of Jargon aphasia based on this background literature. The key criterion adopted was that nonwords were the most common error type in single word production tasks. Further language profiling was completed to examine the comprehension, repetition and fluency abilities associated with nonword production.

Table 2.2: Participant demographics and language profiles used to support identification of Jargon aphasia

				Boston Diagnostic Aphasia Examination Percentiles			
Pt code	Age (years)	Sex	Time post stroke (months)	*Auditory comprehension*	*Fluency*	*Repetition*	Nonwords (%)
T1	70	M	42	45	>99	27.5	28
T2	60	M	5	7	84	7.5	30
T3	59	M	6	17	>99	20	39
T4	74	M	6	12	51	12.5	50
T5	64	M	6	10	68	15	51
T6	77	M	24	40	90	25	56
T7	78	F	72	5	68	10	57
T8	86	M	13	10	80	7.5	71
T9	53	M	7	15	68	<1	73
T10	73	M	6	3	63	<1	91
T11	90	M	27	47	87	>99	7
T12	71	M	78	20	>99	7.5	37
T13	56	F	37	13	73	22	50
T14	61	M	11	31	67	45	63
T15	71	M	33	16	25	8	60
T16	74	F	9	37	88	8	69
T17	78	M	24	13	90	15	85
T18	61	M	42	18	78	<1	93
T19	85	M	33	53	90	5	94
T20	84	F	58	30	40	<1	96

Nonwords indicate the percentage of responses which were classified as nonlexical on tasks of single word production.

2.5 ***Jargon aphasia language profiles***

2.5.1 Speech characteristics

The speech rating section from The Boston Diagnostic Aphasia Examination short form (BDAE; Goodglass, Kaplan, & Barresi, 2000) was used to support the identification of Jargon-like profiles. By this assessment, participant speech characteristics are rated on eight different parameters. Firstly, articulatory agility, described as the ability to produce phonemes and syllables, is rated by the experimenter between 1 (unable to form speech sounds) and 7 (no impairment in forming speech sounds). Phrase length is rated on the longest occasion of uninterrupted word runs between one word (minimum score) and seven or more words (maximum rating). Grammatical variety and melodic line are rated on the same scale between zero (indicating severe impairment in grammar and prosody) and seven (typical syntax and prosody). Experimenter ratings also include the proportion of connected speech which contains a paraphasia (1 = present in every utterance, 7 = absent in connected speech) and word finding relative to fluency (1 = fluent but empty speech and 7 = output comprises content words). The remaining two speech characteristics are calculated based on test scores on sentence repetition (repetition subtest score) and auditory comprehension (comprising single word and command comprehension and ability to answer abstract questions). Across all the components a high score indicates little or no impairment. To enable comparison across rating and percentile scores, all rating scores (originally scored from 7) were converted to a percentage score. All participants in the current thesis completed the relevant subsections of the BDAE and their speech profiles were analysed and scored.

2.5.2 Participant lesion and language profiles

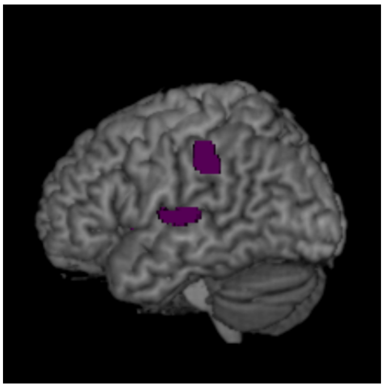
Lesion profiles are presented for the Jargon participants for whom neuroimaging data were available. Subsequently, the lesion drawing for each participant was presented using MRIcron and is presented below.

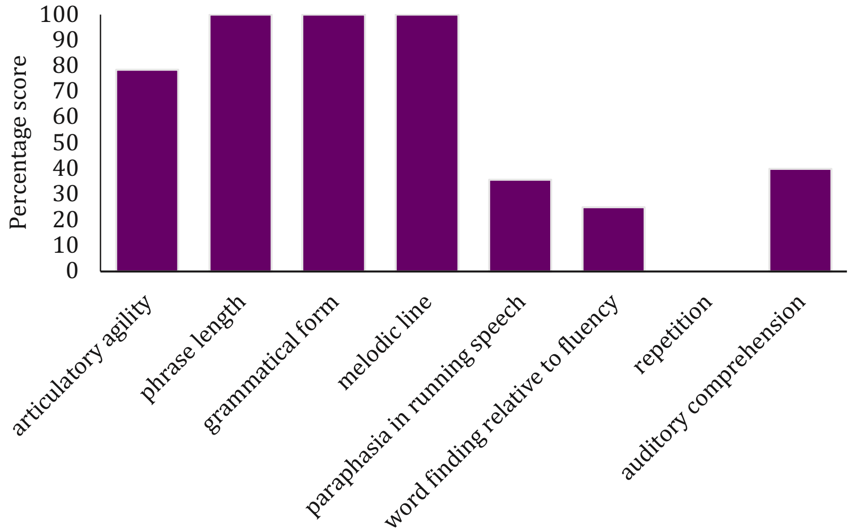
Table 2.3 indicates the nature of the structural scans and whether the structural scans were acquired from research MRI facilities (MR- 3T), clinical Magnetic Resonance imaging (MR – clinical) or clinical CT imaging (CT – clinical). Participants T1, T2, T3, T6, T8 and T10 were recruited and scanned using facilities at the University of Manchester on a 3T Phillips Achieva scanner, whilst research MR imaging data for participants T11, T12, T15, T17 and T18 were acquired on a Siemens Magnetom Trio 3T MRI scanner at the University of Reading. For the majority of participants, lesion masks were drawn manually using MRIcron software (Rorden & Brett, 2000) and normalised using SPM8 (https://www.fil.ion.ucl.ac.uk/spm). For participants T1, T2, T3, T6, T8 and T10, lesions were automatically extracted using the ALI SPM toolbox (Seghier et al., 2008). This process involved normalising and segmenting each brain scan into grey matter, white matter and cerebrospinal fluid and then comparing the images to a group of 10 age-matched neuro-typical participants to identify significant deviation in brain structure. A lesion overlap map was created by overlaying the individual normalised masks using MRIcron. Subsequently, the lesion drawing for each participant was presented using MRIcron and is presented below.

Table 2.3: Neuroimaging data source

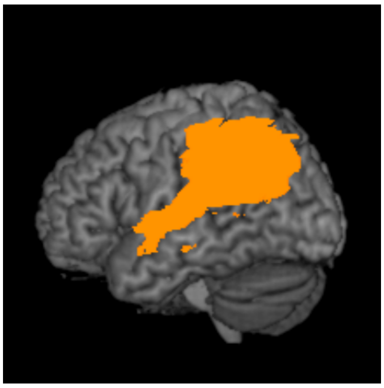
Participant code	Imaging
T1	MR - 3T
T2	MR - 3T
T3	MR - 3T
T4	CT - clinical
T5	CT - clinical
T6	MR - 3T
T7	Unavailable
T8	MR - 3T
T9	CT - clinical
T10	MR - 3T
T11	MR - 3T
T12	MR - 3T
T13	CT - clinical
T14	Unavailable
T15	MR - 3T
T16	CT - clinical
T17	MR - 3T
T18	MR - 3T
T19	MR - clinical
T20	Unavailable

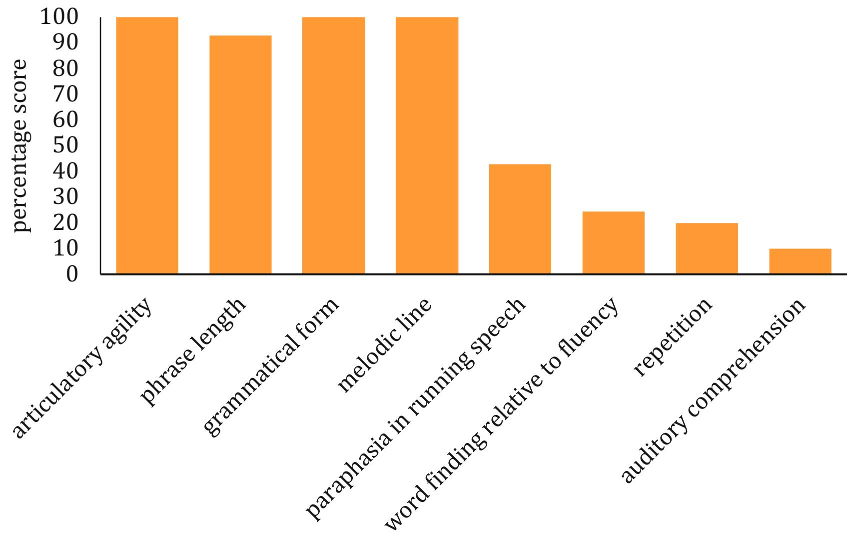
Participant T1



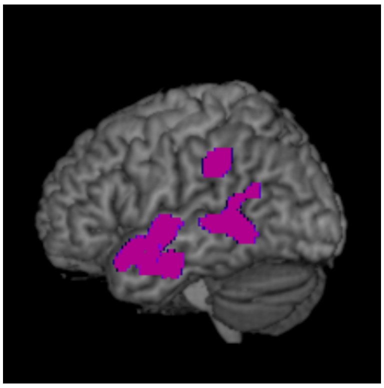


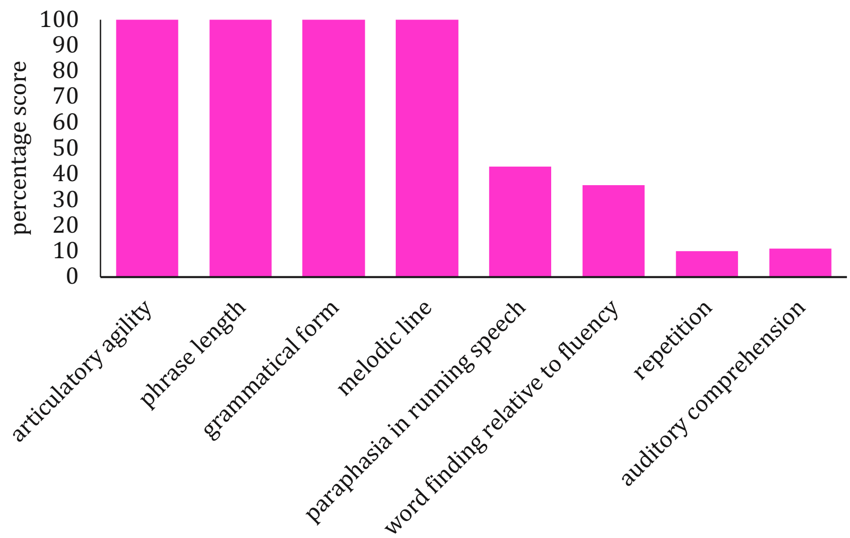
Participant T2



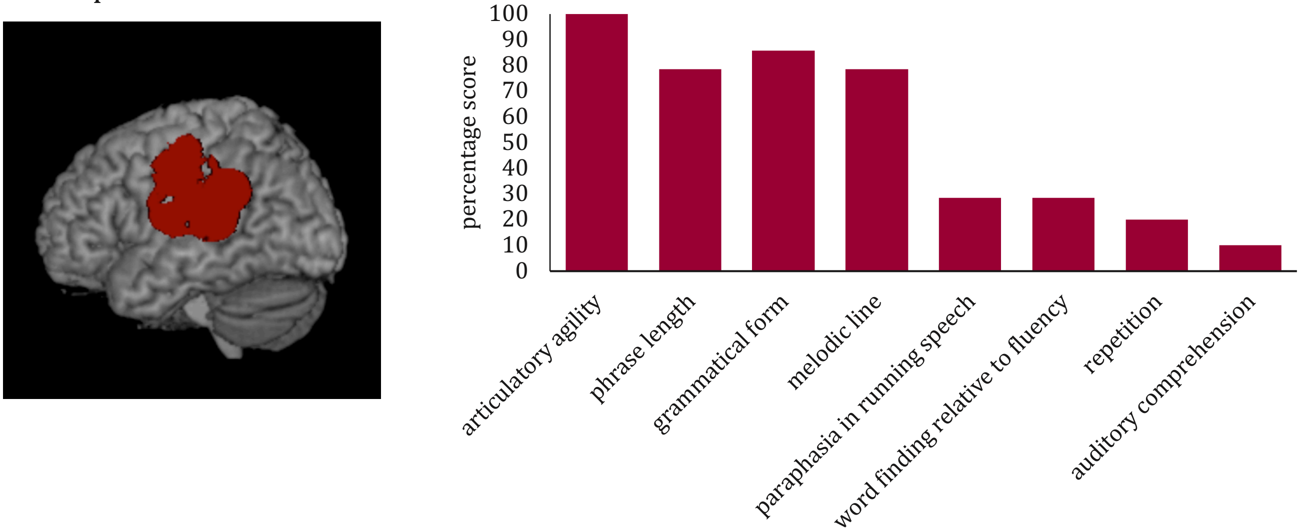


Participant T3

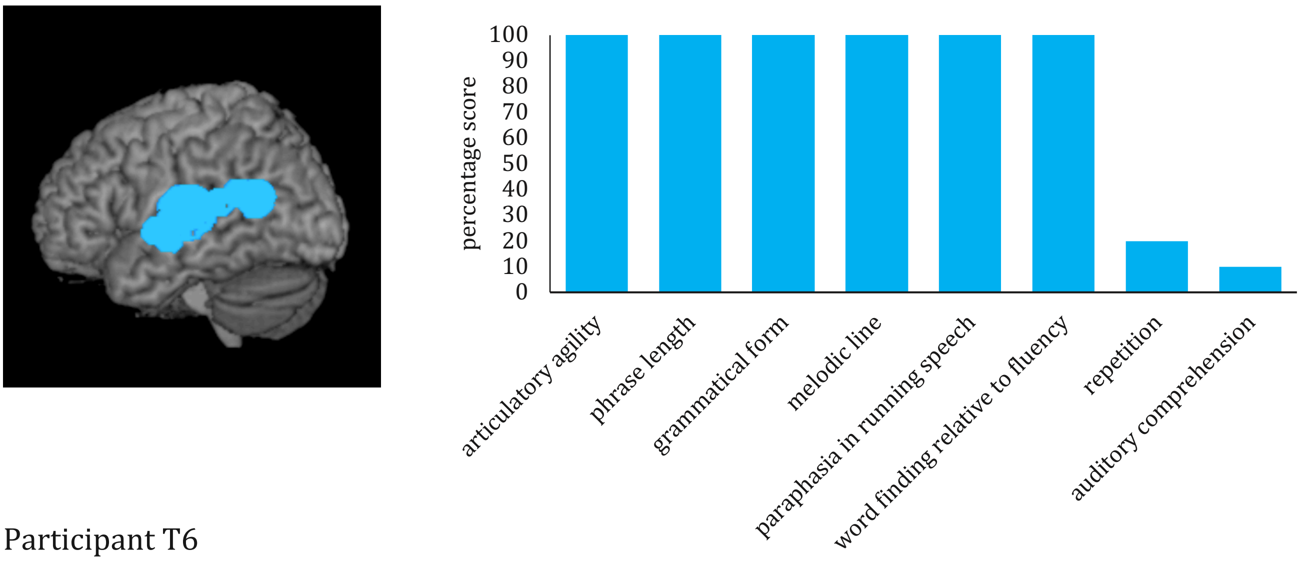




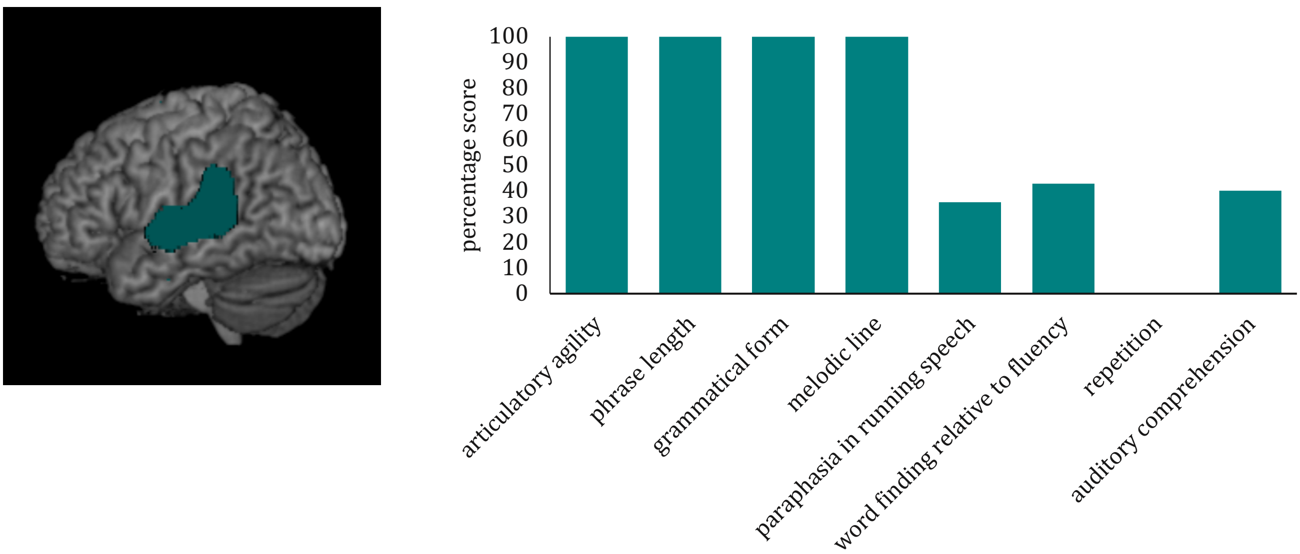
Participant T4



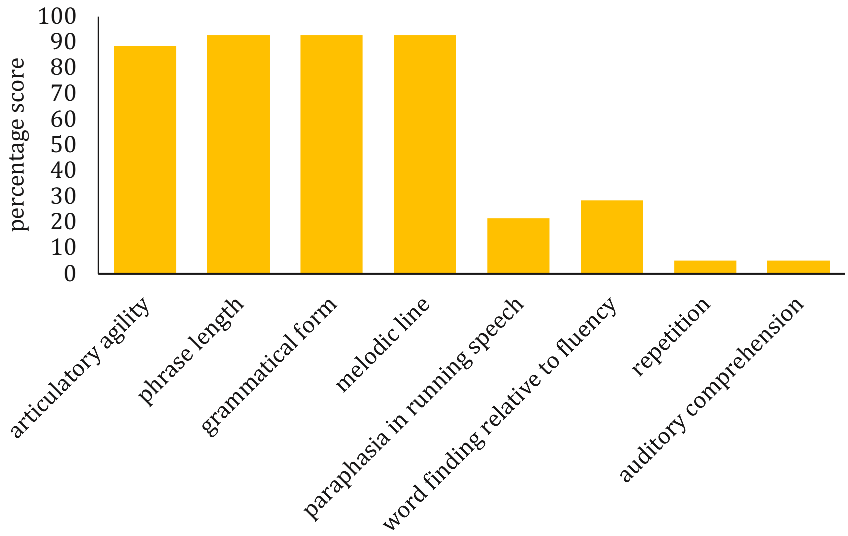
Participant T5



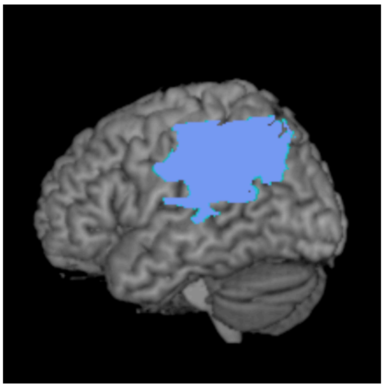
Participant T6

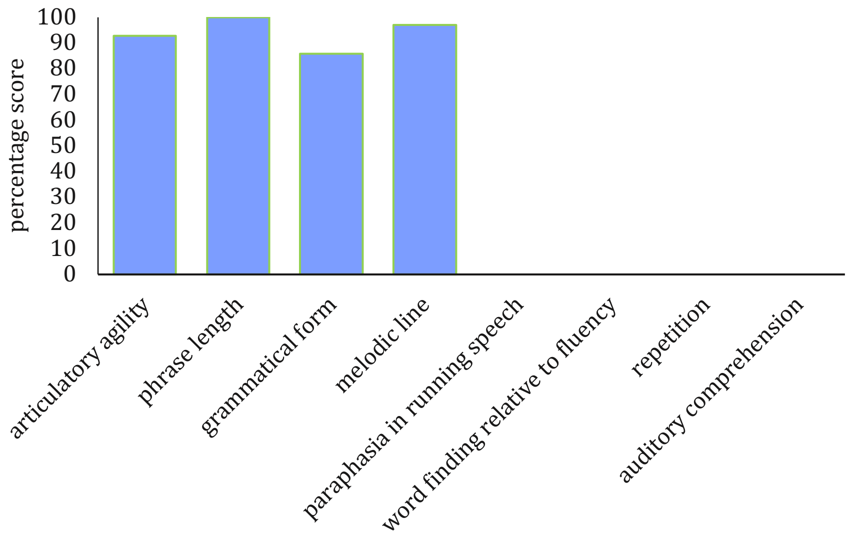


Participant T7

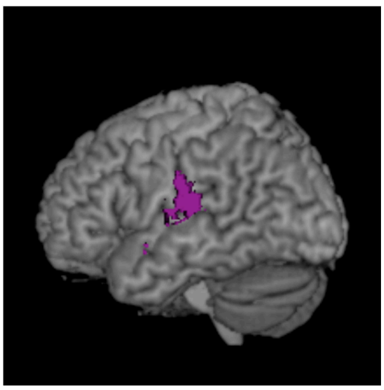


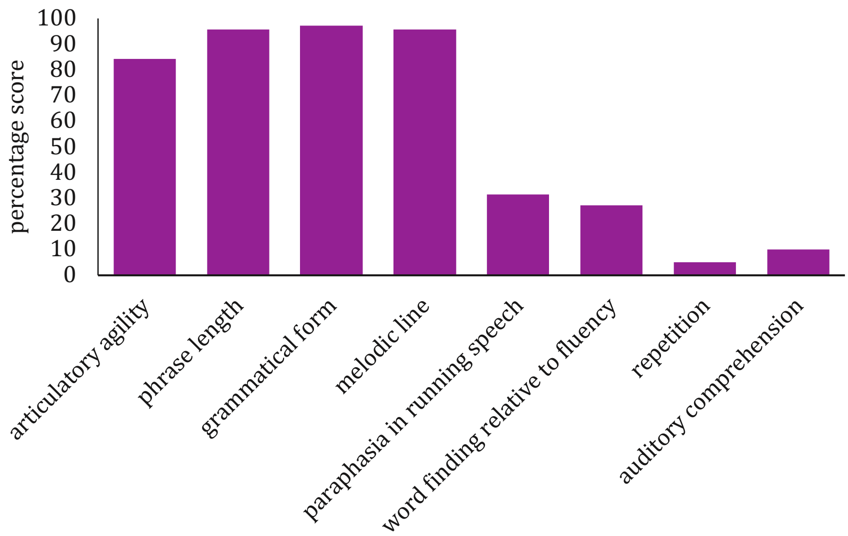
Participant T8



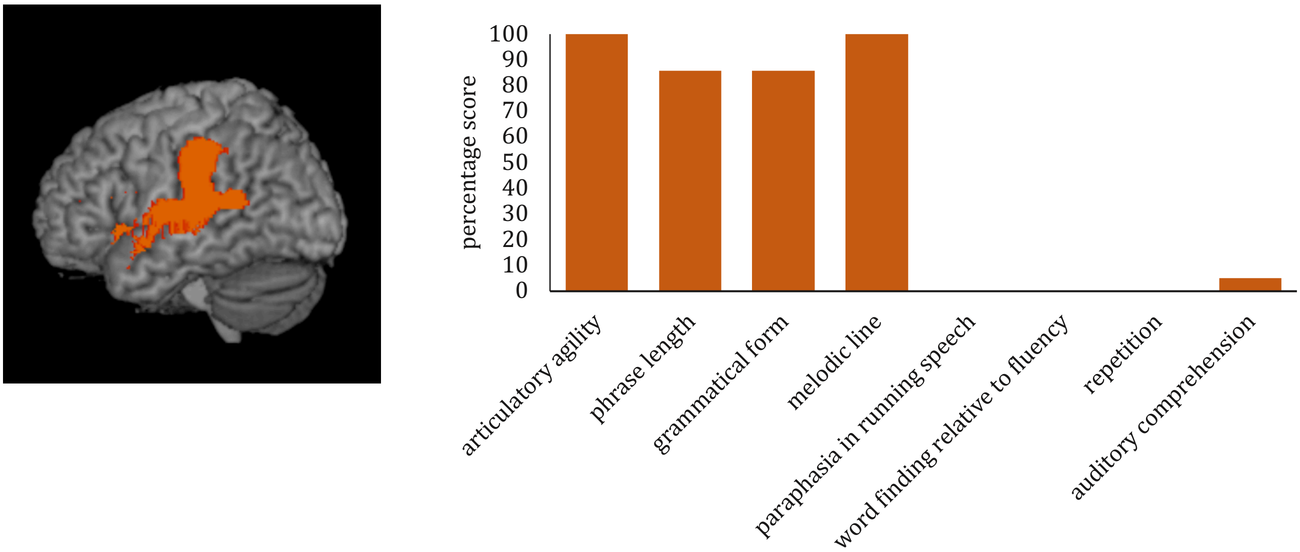


Participant T9

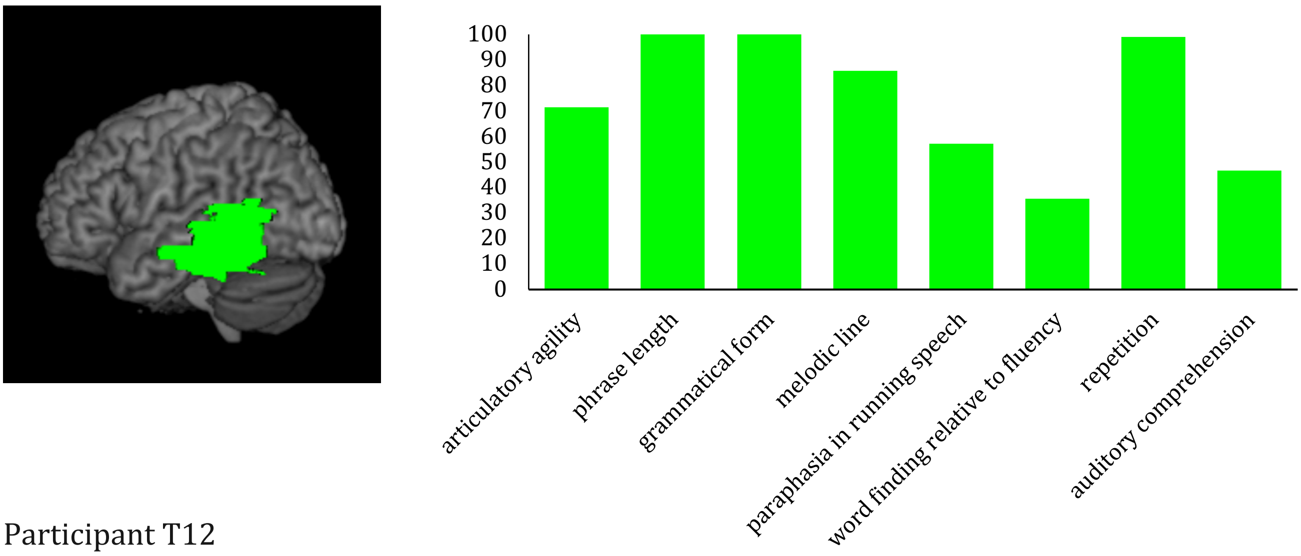




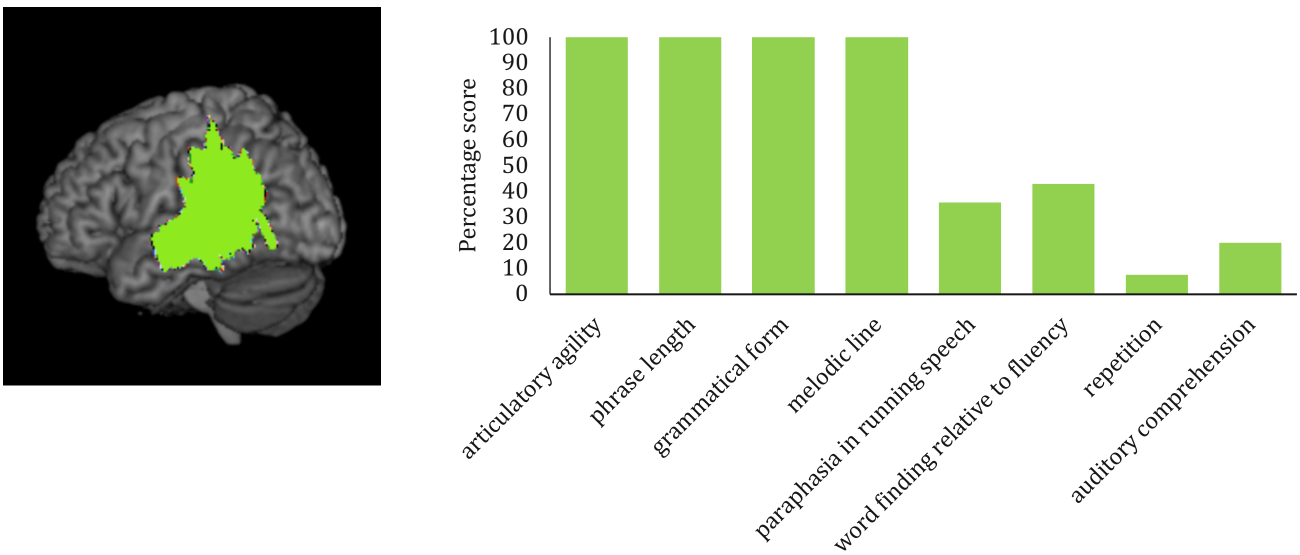
Participant T10



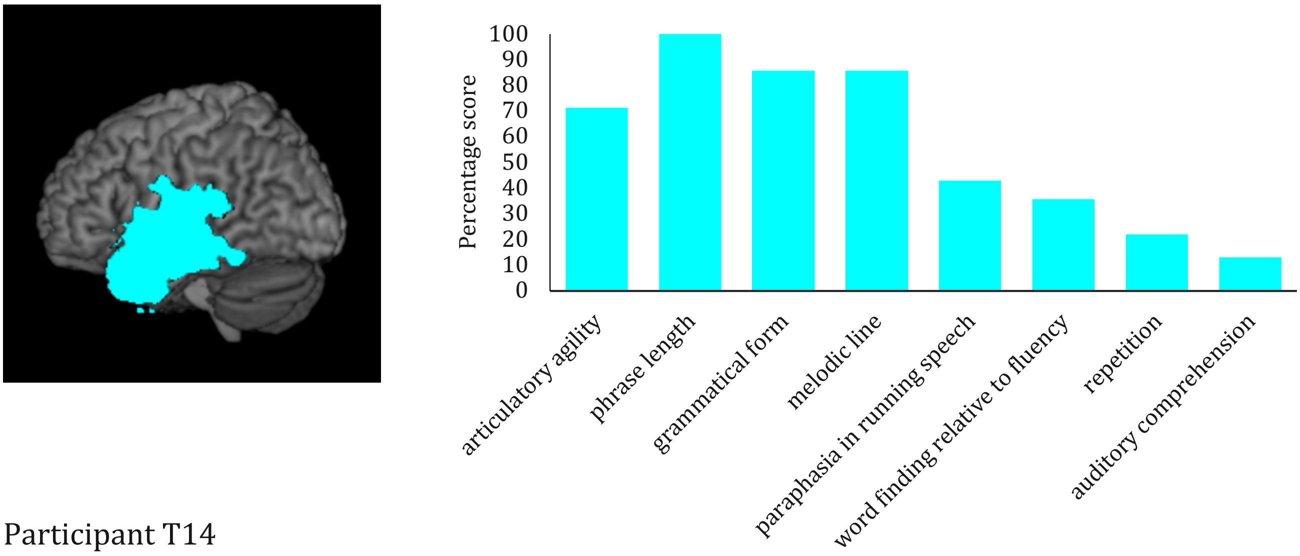
Participant T11



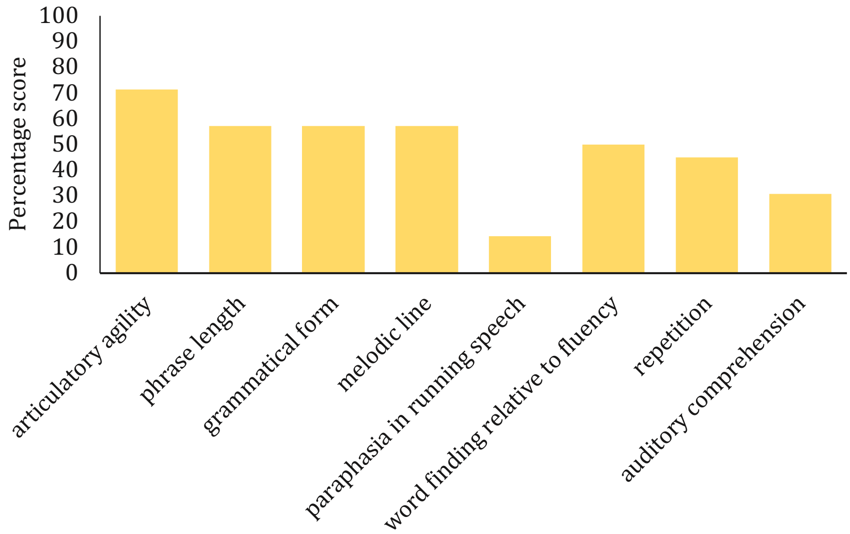
Participant T12



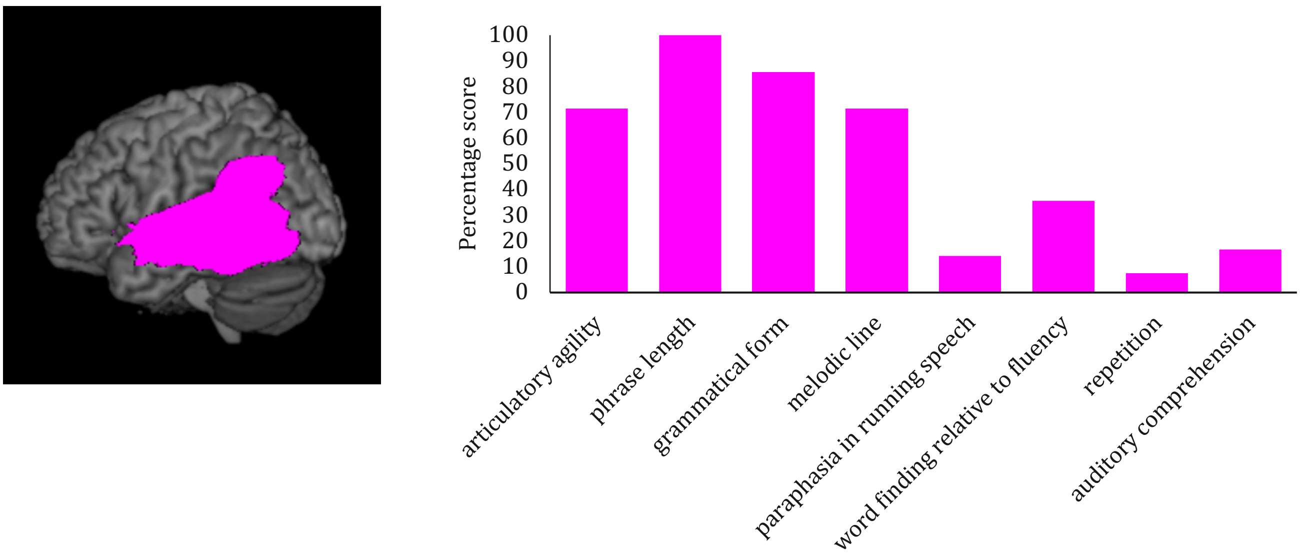
Participant T13



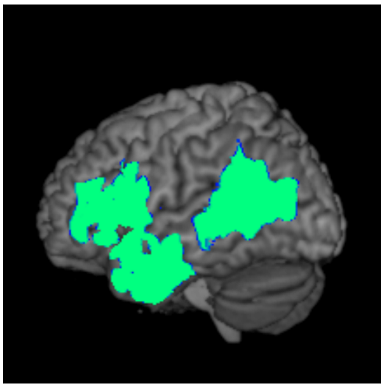
Participant T14

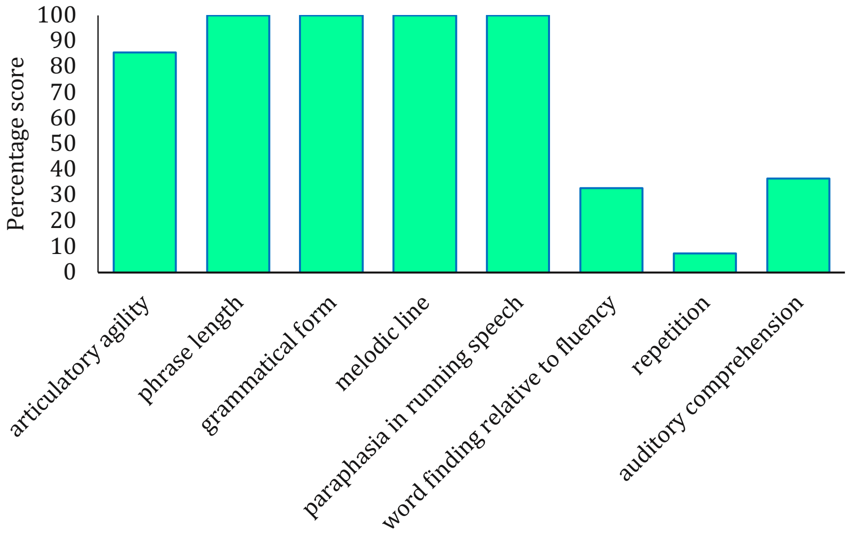


Participant T15

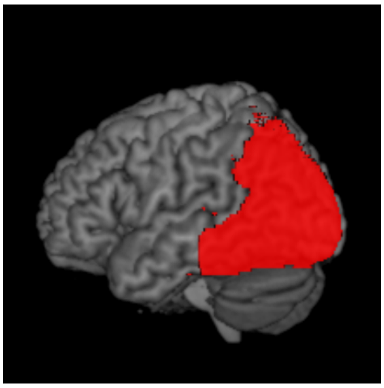


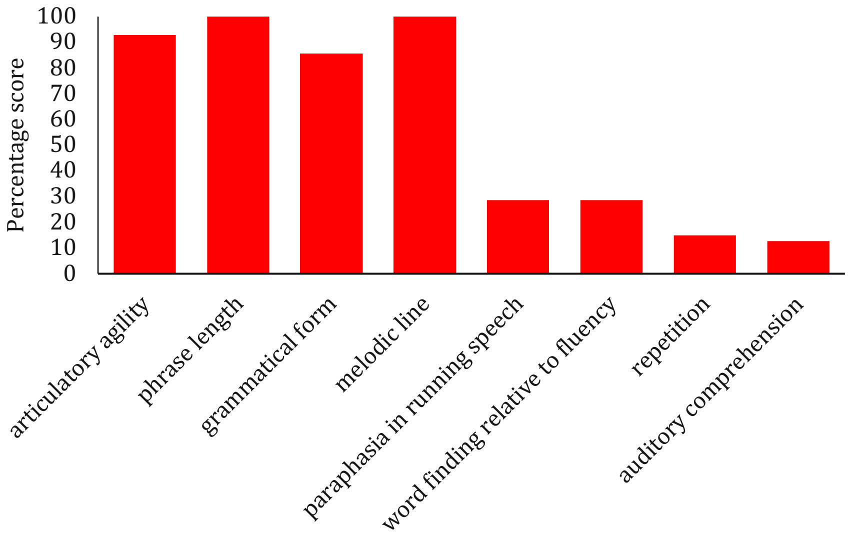
Participant T16



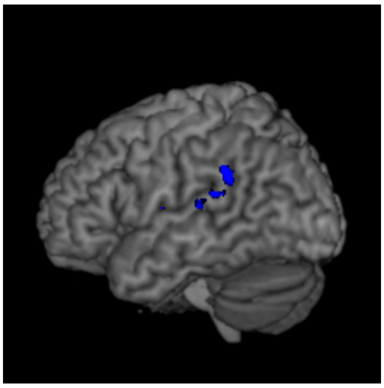


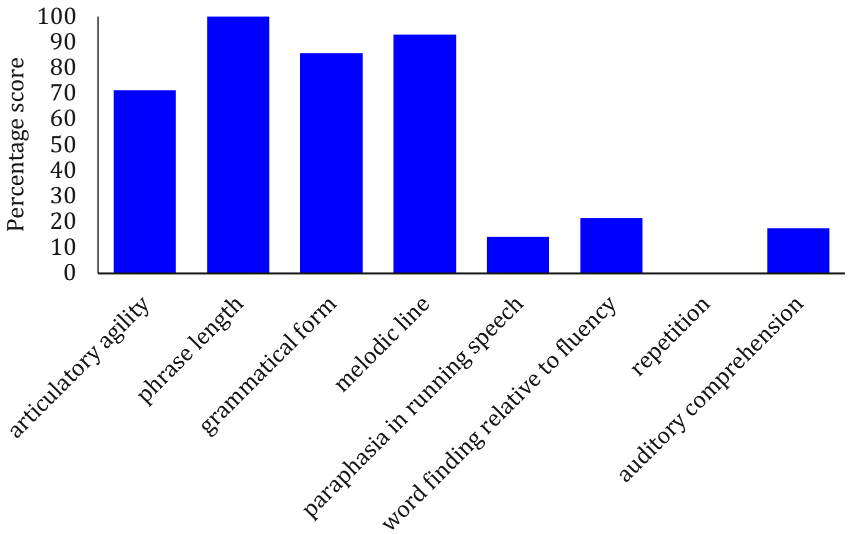
Participant T17



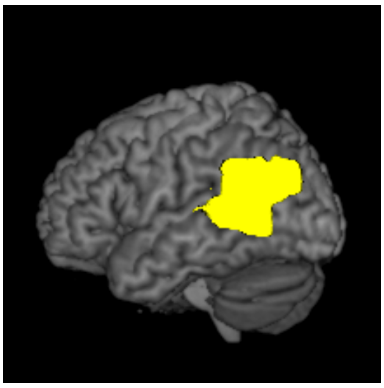


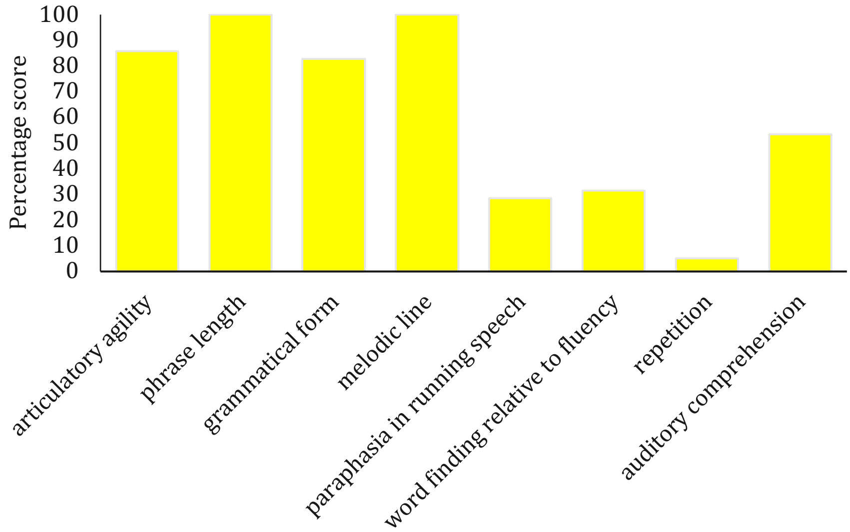
Participant T18



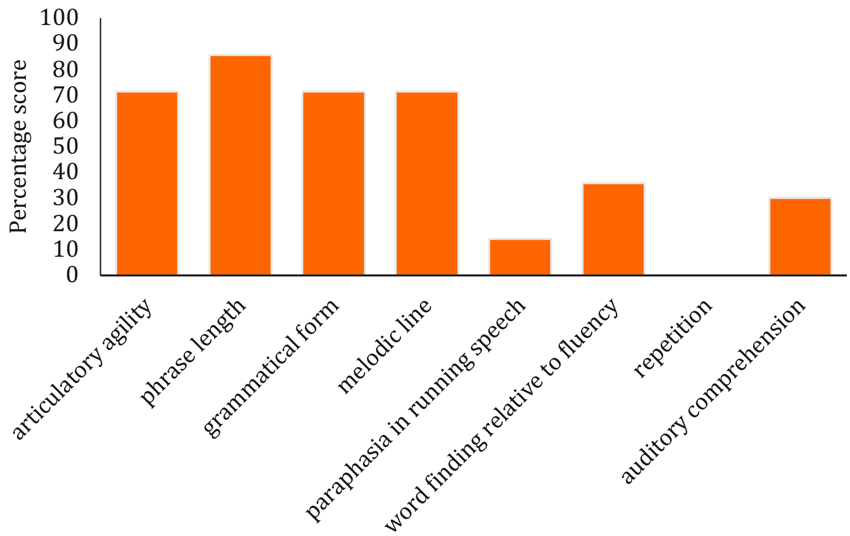


Participant T19





Participant T20



2.5.3 Average language profile

The ratings on each BDAE component were averaged together across all participants to support the identification of common features associated with Jargon aphasia. Figure 2.1 demonstrates that generally there is little or no impairment in articulation and phrases produced by the participants tended to comprise six or seven items with appropriate grammar. The prosody of Jargon speech is also preserved in this group of participants. Overall, the connected speech lacks content words and paraphasias are often produced, alongside impaired repetition and poor auditory comprehension. This pattern conforms to existing accounts of Jargon aphasia (Buckingham & Kertesz, 1976; Brown, 1981; Marshall, 2006).

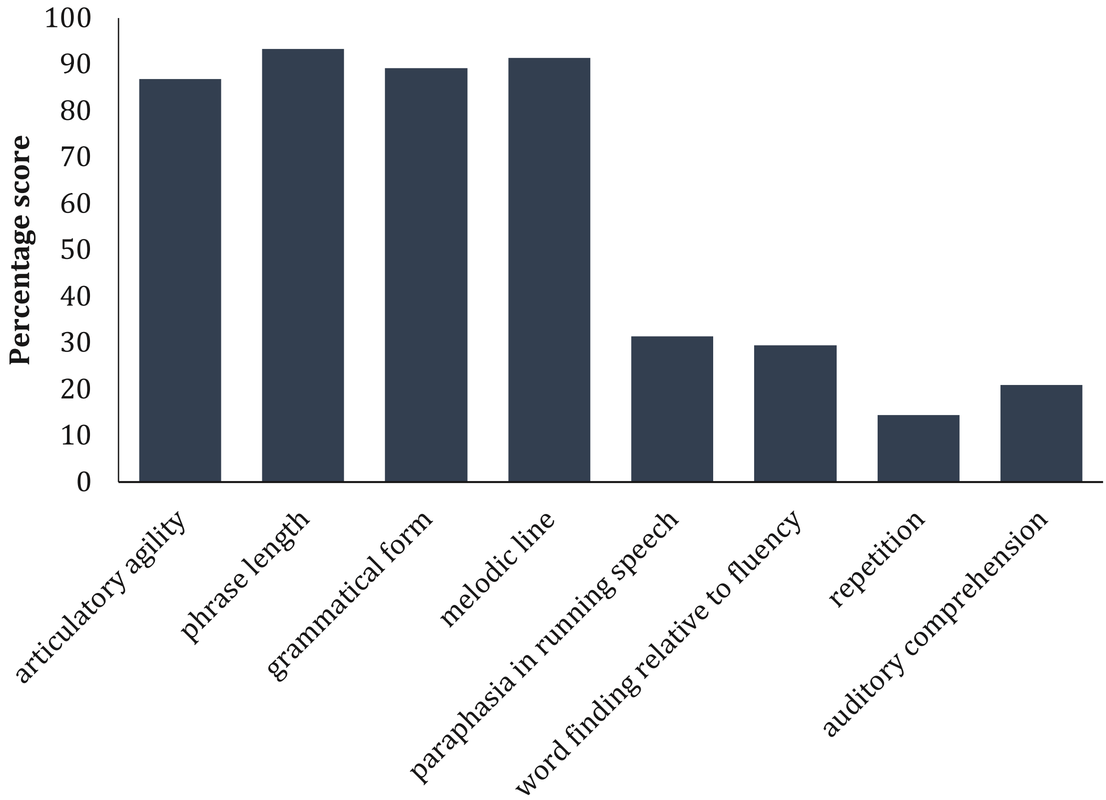


Figure 2.1: Average language profile for 20 participants with Jargon aphasia

2.5.4 Lesion overlap map for Jargon participants

For all participants with lesion data available, a lesion overlap map was generated using MRIcron. This procedure overlays each individual lesion on top of one another and on top of a standard template to support identification of neural regions with high lesion overlap. The automated anatomical labelling atlas which is inbuilt within MRIcron was used to confirm the neural regions where high lesion overlap occurs. This demonstrated that fifteen from the seventeen participants included in this analysis had lesions in a small cluster of voxels located at the superior portion of the superior temporal gyrus and the inferior portion of the supramarginal gyrus (see Figure 2.2). Regions of lower overlap (N = 11) were observed in lateral portions of the superior temporal gyrus and the middle portion of the middle temporal gyrus.

There exist very few larger reports of the lesion profile associated with Jargon production; however, a number of case studies provide specific descriptions of the lesion location observed in individual participants, reporting damage to the left posterior regions including the Superior Temporal Gyrus (Bose, 2013; Kohn et al., 1996), parietal regions (Bose, 2013; Eaton et al., 2010; Olson et al., 2015) and the basal ganglia (Moses et al., 2004; Olson et al., 2015). Neural damage is also reported to extend to wider regions, including the occipital lobe (Eaton et al., 2010), and sometimes extend across both hemispheres (Robson et al., 2003). Group studies which provide lesion information from people with Jargon-like aphasia conform to these case reports, demonstrating high lesion overlap in middle and posterior portions of the superior and middle temporal gyri and the temporo-parietal junction (Kertesz, 1981; Pilkington et al., 2017).

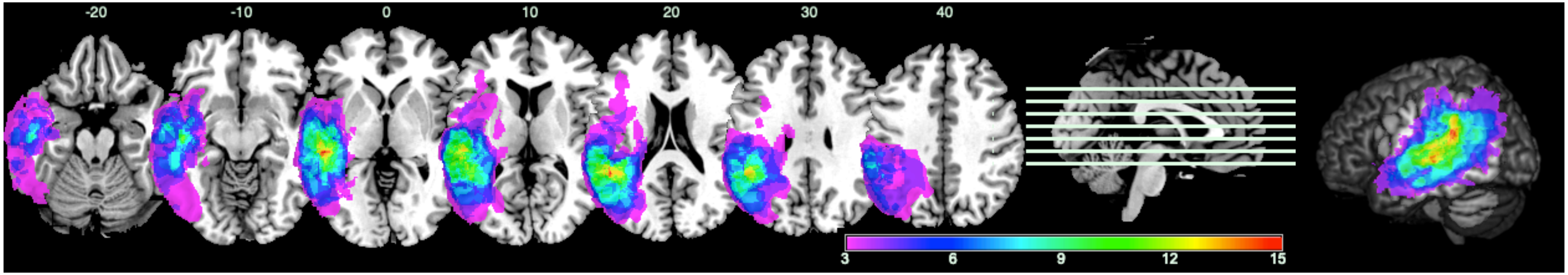


Figure 2.2: Lesion Overlay for 17 Jargon participants for whom lesion data were available. Colour bar represents the number of participants presented across the colour spectrum. MNI Z co-ordinates are presented above slices.

Chapter 3. What can repetition, reading and naming tell us about Jargon aphasia?

Emma Pilkington[a*], Karen Sage[b], James Douglas Saddy[a], and Holly Robson[a]

[a]*School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK.*
[b]*Department of Allied Health Professions, Sheffield Hallam University, Sheffield, UK.*

**School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK, RG6 7BE. E.c.pilkington@pgr.reading.ac.uk*

Chapter 3 information

This chapter/manuscript was accepted for publication in the *Journal of Neurolinguistics* in August 2018 *(Journal of Neurolinguistics 49 (2019) 45–56).* The data within this chapter were collected by Holly Robson as part of her PhD research in comprehension deficits in Wernicke's aphasia. Study design, data processing and analysis, interpretation and manuscript preparation were all completed independently by Emma Pilkington.

Authorship statement

E. Pilkington: conceptualisation; methodology; resources (recruitment and data collection), curation and analysis; manuscript preparation; visualisation; funding acquisition.
K. Sage: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
D. Saddy: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
H. Robson: conceptualisation; methodology; resources (participant recruitment and data collection); manuscript review and editing; supervision; funding acquisition.

3.1 *Abstract*

Jargon Aphasia is an acquired language disorder characterised by high proportions of nonword error production, rendering spoken language incomprehensible. There exist two major hypotheses relating to the source of nonword error; one implicates disruption to phonological processing and the other suggests both phonological and lexical contributions. The lexical sources are described as failure in lexical retrieval followed by surrogate phonological construction, or a lexical selection error further compounded by phonological breakdown. The current study analysed nonword error patterns of ten individuals with fluent Neologistic Jargon aphasia in word repetition, reading and picture naming to gain insights into the contributions of these different sources. It was predicted that, if lexical retrieval deficits contribute to nonword production, naming would produce a greater proportion and severity of nonword errors in comparison to repetition and reading, where phonology is present and additional sub-lexical processing can support production. Both group and case series analyses were implemented to determine whether quantity and quality of nonwords differed across the three production tasks. Nonword phoneme inventories were compared against the normative phoneme distribution to explore whether phonological production takes place within a typically organised, lexically constrained system. Results demonstrated fewer nonword errors in naming and a tendency for nonwords in naming to be characterised by lower phonological accuracy. However, nonwords were, for the most part, constructed with reference to target phonological information and, generally, nonword phonological production patterns adhered to the statistical properties of the learned phonological system. While a subset of the current group demonstrated very limited lexical processing capacity which manifested as nonword errors in naming being most disrupted, overall the results suggest that nonwords are largely underpinned by some degree of successful lexical retrieval and implicate phonological sources, which manifest more severely when production is accomplished via nonlexical processing routes.

Keywords: Jargon aphasia; nonword; neologism; Phonological Overlap Index (POI); word production

3.2 ***Introduction***

3.2.1 Nonword production

Jargon aphasia is a form of acquired language impairment characterised by nonword errors in spoken production. Nonwords occur across all output tasks, and the presence of nonwords within connected speech renders spoken production incomprehensible (Marshall, 2006). Efforts to elicit nonword errors in neurologically healthy speakers have applied external manipulations such as phonological priming and response pressure to word production tasks. However, real words, i.e. words with existing conceptual and lexical representations, continue to dominate output, whilst nonword errors are rarely realised (Baars, Motley, & MacKay, 1975; Goldrick & Blumstein, 2006; Vitevitch, 2002). This failure to prime nonword errors to the same extent at which they are observed within the Jargon aphasia population limits understanding of the mechanism(s) underlying nonword production and hinders the development of hypotheses attempting to explain how such production comes to dominate in a form of acquired language impairment.

Despite this, there exist a number of theoretical accounts pertaining to nonword error generation, mostly derived from studies of picture naming in clinical populations. The most widely accepted hypothesis postulates that nonwords stem from a *single* impairment source – a deficit in phonological encoding. The phonological encoding account states that deficient activation of target phonological segments for output allows alternative phonemes to compete and intrude, giving rise to non-target phonology in production (Kertesz & Benson, 1970). Nonwords with high proportions of target phonology (paraphasia, e.g. village, /lɪvɪdʒ/) are hypothesised to arise through mild disruption to this stage of phonological processing, whereas errors with little or no target phonology (neologism, e.g. tribute, /kraɪbri:/) are thought to follow more significant disruption during segment selection and organisation. By this hypothesis paraphasias and neologisms occupy opposite ends of a single continuum of nonword severity and the majority of nonwords fall somewhere in between and contain moderate degrees of target phonology (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Olson, Halloran, & Romani, 2015; Olson, Romani, & Halloran, 2007; Schwartz, Wilshire, Gagnon, & Polansky, 2004). However, some case studies document evidence that challenge this hypothesis, reporting individuals who produce significant proportions of nonwords that share very little or no target phonology and high proportions of non-target phonological segments. Such observations have given rise to alternative hypotheses which propose that nonwords stem from a *dual* impairment in lexical and phonological processing. Under such hypotheses, severe neologisms are underpinned by a separate or additional lexical retrieval deficit. One such hypothesis suggests that severe distortions occur when the lexical representation belonging to the target word is unable to be retrieved and subsequently a surrogate phonological string is assembled for output, without reference to the target representation (Buckingham, 1977; 1990; Butterworth, 1979, 1992; Butterworth, Swallow, & Grimston, 1981; Buckingham, 1977). A complementary hypothesis suggests that severe neologisms are formed by compound errors, in which erroneous lexical selection is followed by faulty phonological encoding (Schwartz, Wilshire, Gagnon, & Polansky, 2004). Evidence for the single and dual source hypotheses can be examined by exploring the phonological accuracy of nonwords and the distribution of this accuracy. A single phonological locus (one source) would generate a majority of errors containing moderate levels of target phonology, since nonword construction follows appropriate lexical retrieval. Additionally, there would be a comparative scarcity of errors with few/significant portions of target phonology, thus eliciting a normal distribution of accuracy (Olson et al., 2007; 2015; Pilkington et al., 2017; Schwartz et al., 2004). A separate lexical deficit would generate an independent error population, characterised by a significant proportion of responses containing chance levels of target phonology, secondary to surrogate phonological usage in the absence of a specified lexical target or phonologically distorted lexical errors. The coexistence of lexical and phonological error sources would be reflected in a bimodal distribution of accuracy and has been illustrated in some case studies of Jargon individuals (Buckingham & Kertesz, 1976; Kohn et al., 1996).

3.2.2 Production task differences

An alternative approach to differentiating between the single and dual source hypotheses is to analyse production patterns across separate output tasks which are characterised by different lexical and phonological processing demands. Specifically, picture naming requires independent semantic and lexical retrieval prior to phonological encoding, such that errors arising through lexical processes, either default phonological selection secondary to lexical failure, or compound lexical and phonological errors should be more likely in this task, and so a greater number of nonword errors should occur, if a lexical source exists. Furthermore, given that some of these errors are characterised by lexical selection errors/failures, the quality of nonword errors in naming should be affected, with lower accuracy in phonological production expected (Olson et al., 2007). Reading and repetition can be supported by both lexical and nonlexical processes concurrently and so fewer nonwords should be observed in these tasks, since nonlexical processing can support and facilitate production, thereby allowing production to be accomplished with less weight on lexical retrieval (Coltheart, Curtis, Atkins & Haller, 1993; Roelofs, 2004). Since phonological encoding is common in all three production tasks, a single phonological locus would elicit similar numbers of nonword errors across tasks. However, previous production task comparisons in Jargon aphasia have produced inconsistent results. The nature and number of nonword errors produced in repetition, reading and naming has been observed to be relatively consistent in some individuals with Jargon aphasia (Moses, Nickels, & Sheard, 2007; Olson et al., 2007; 2015) whereas other cases have presented with greater nonword errors in naming than in other production tasks including reading and repetition (Ackerman and Ellis, 2007; Corbett, Jeffries, & Lambon-Ralph, 2008; Moses, Nickels, & Sheard, 2004). Importantly, much of this previous evidence is derived from single case studies or includes individuals with mixed behavioural profiles and relatively mild Jargon deficits, limiting the applicability and relevance of these conclusions to individuals with more severe production deficits.

3.2.3 Jargon phonological inventories

Further evidence into the source of nonword errors can be gained by exploring the phonological inventories of individuals with Jargon aphasia. Phonological inventories, the frequency of occurrence of each phonological segment within an individual's nonword inventory, reflects the statistical properties of the phonological system and suggests whether a lexical influence remains over production, as the phonological segment selection is inherently linked and influenced by a word's lexical representation. A number of Jargon aphasia cases have been identified in which individuals present with idiosyncratic phonological usage. This indicates that the phonological system does not retain its statistical structure and that nonwords may not be constrained by lexical processing and supporting the total lexical retrieval failure hypothesis (Butterworth, 1979; Eaton, Marshall, & Pring, 2010; Moses et al., 2004). Originally, such patterns were proposed to arise from a neologism generating device or mechanism (Buckingham, 1990; Butterworth, 1979). However, an alternative interpretation is that idiosyncratic phonological useage arises through long term disruption to phonological encoding, which distorts the phonological system and the frequency at which each individual segment resides (Eaton, Marshall, & Pring, 2010; Moses et al., 2004; Robson, Pring, Marshall, & Chiat, 2003).

3.2.4 The current study

In the current study, we apply these methodological approaches to a case series of individuals with neologistic Jargon aphasia to draw inferences regarding the source(s) of impairment and functioning of the phonological system. Single word naming, reading and repetition data were collected from ten participants with Jargon aphasia. We analyse the prevalence of nonword errors across the three separate production tasks and examine the phonological accuracy of nonword responses to understand whether nonword errors manifest differently in the separate tasks. We also explore whether phonological segment frequency within nonwords conforms to typical English frequencies to determine whether production is constrained by a typically organised lexical-phonological processing system.

3.3 ***Methods***

3.3.1 Participants

Ethical approval for this project was gained from the North West NHS Research Ethics Committee. Ten individuals (one female; age $\bar{x}$ = 69 years, σ = 10.2 years; time post onset $\bar{x}$ = 19 months, σ = 22.15 months) with Jargon aphasia are reported. Data were collected by the last author between 2009 – 2011 and all participants gave informed consent. All ten individuals produced high proportions of neologistic and/or paraphasic errors, with fluent speech and impaired single word comprehension (see *Table 3.1*). . All ten individuals were classified as having Wernicke's Aphasia at the time of data collection, according to the Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2001).

Table 3.1: Demographic and Boston Diagnostic Aphasia Examination (BDAE) short form percentile results.

				BDAE percentile scores			
Pt code	Age (years)	Sex	Time post onset (months)	Comprehension	Fluency	Word repetition	Sentence repetition
p1	70	M	42	45	>99	15	40
p2	60	M	5	6.5	84	5	10
p3	59	M	6	17	>99	10	30
p4	74	M	6	12	51	10	15
p5	64	M	6	10	68	15	15
p6	77	M	24	40	90	5	45
p7	78	F	72	5	68	5	15
p8	86	M	13	10	80	5	10
p9	53	M	7	15	68	<1	<1
p10	73	M	6	3	63	<1	<1

Note. Participants ordered by the total number of nonwords produced across the three production tasks from fewest (p1) to highest (p10).

3.3.2 Tasks

Participants undertook three single word production tasks – picture naming, reading and repetition. The picture naming test from the Cambridge Semantic Battery (Adlam, Patterson, Bozeat, & Hodges, 2010) consisted of 64 black and white line drawings from the Snodgrass and Vanderwart set. Reading and repetition tests were 80-item subtests from the PALPA (Psycholinguistic Assessment of Language Processing in Aphasia, subtests 9 and 31: Kay, Lesser, & Coltheart, 1996). To make the naming, reading and repetition tests numerically equivalent, a subset of 64 PALPA items were selected based on frequency ratings from N-Watch (Davis, 2005) and the MRC psycholinguistic database (Coltheart, 1981). The repetition and reading sets included the same 64 target items (see Appendix 1) which had a mean frequency of 47.98 (σ = 1.40), mean familiarity 512.245 (σ = 69.96), mean imageability 431 (σ = 175.99), average number of letters 5.89 (σ = 1.40), mean number of phonemes 5, (σ = 1.49) and average syllable number 2.03 (σ = 0.76). The picture naming items had a similar mean frequency ($\bar{x}$ = 28.37, σ = 56.60, t(109) = 1.945, p = .0543), familiarity ($\bar{x}$ = 514.02, σ = 73.66, t(107) = 0.128, p = .898), imageability ($\bar{x}$ = 396, σ = 291.10, t(126) = 0.807, p = 0.421), letter number ($\bar{x}$ = 6.17, σ = 2.16, t(126) = 0.874, p = .384), phoneme number ($\bar{x}$ = 4.918, σ = 1.85, t(126) = 0.103, p = .785) and syllable number ($\bar{x}$ = 1.90, σ = 0.80, t(126) = 0.914, p = .359) to the repetition/reading tasks.

3.3.3 Recording and error coding

Responses were transcribed into DISC symbols (1:1 phoneme: symbol correspondence, i.e. IPA = [i:], DISC = [i]); to enable automated data extraction via Microsoft excel. When multiple responses were given, the final complete utterance was accepted. Correct responses were identified, all non-lexical responses were labelled as nonwords, and remaining errors types were labelled according to their relationship with the target word, in line with methods adopted in Dell et al., (1997).

3.3.4 Analyses

3.3.4.1 Group error prevalence

For each participant, the number of correct responses, nonword errors and other error types were counted. The number of nonwords observed from each participant on each production task (repetition, reading, naming) was entered into a one way repeated measures ANOVA to examine whether the number of nonword errors differed across repetition, reading and naming at the group level.

3.3.4.2 Phonological accuracy of nonwords

3.3.4.2.1 Observed accuracy

The Phonological Overlap Index (POI) (number of phonemes shared between response and target x2)/(total phonemes in target + total phonemes in response) (Bose, 2013; Schwartz et al., 2004) was calculated for each nonword. This calculation assigns responses which contain all appropriate target phonemes a value of one, and responses which contain no target segments a value of zero. When all appropriate phonemes are selected, irrespective of their order a nonword would attain a value of one (e.g. village,

/lɪvɪdʒ/). A one way repeated measures ANOVA was used to determine whether phonological accuracy (POI) differed across repetition, reading and naming. To determine whether phonemes were accurately encoded at the individual level, average POI values for each participant on each production task were compared against a chance level of accuracy via a bootstrapping procedure.

3.3.4.2.2 Chance phonological accuracy

A chance phonological overlap (POI) statistic represents the degree to which any target - response pairing is likely to share phonology. This statistic quantifies the extent to which a nonword will overlap with a target if it were constructed without reference to target phonology and reflects the degree of accuracy expected from random phonological assembly. To calculate chance, all nonword responses produced by the ten individuals within a specific task were collated, along with their corresponding target words. The response and target sets were randomly shuffled, thereby reassigning each nonword error to a new target word. The number of nonwords produced by each individual in each modality was used to determine how many randomly paired responses to sample from the chance sample; for example, where p10 produced 63 nonwords in repetition, 63 random pairings were sampled to derive an individual null distribution. The POI for each new target-nonword pair was calculated and the average across these pairings was derived. This process was repeated 1000 times to yield 1000 chance scores. The observed POI was compared against each chance figure to derive a p statistic for each individual per production task. Confidence intervals for the null distribution were obtained by identifying the chance values observed at the top and bottom 2.5%.

3.3.4.2.3 Phonological accuracy distributions

Individual POI distributions were analysed using the Shapiro Wilk test of normality. Normally distributed POI data are proposed to reflect a single phonological nonword error source. A dual error source is proposed to produce a bimodal distribution. Histograms were visually inspected to assess whether bimodal distributions occurred if testing indicated violation of normality. Where normality was violated, histograms were interpreted to determine whether a bimodal distribution was observed, indicating separate nonword error sources underpinned by failed lexical retrieval and phonological error, or erroneous lexical selection followed by phonological distortion.

3.3.4.3 Phoneme frequency distributions

The frequency of each phoneme in each participant's nonword error set was calculated and compared against the expected phoneme frequency in English, as reported in Denes (1963). Nonword errors were collated across production task to provide sufficient data to run this analysis; focusing on phonemic diversity on a single data point/collection time would make this analysis vulnerable to perseveration and may falsely indicate a distorted phonological inventory. Each individual's phoneme frequency distribution was compared against the normative distribution, using a type two Kolmogorov Smirnov test.

3.4 ***Results***

3.4.1 Group error prevalence

Table 3.2 reports the number of nonword errors produced by each of the ten participants across repetition, reading and naming. A one-way repeated measures ANOVA was used to determine whether numbers of nonword error differed across task (repetition, reading, naming). There was a significant effect of production task on the numbers of nonword production ($F(2, 18) = 4.840$, $p = .021$, $\eta p^2 = .350$, see Figure 3.1) and post hoc - pairwise comparisons tests applying Bonferroni correction identified that picture naming elicited significantly fewer nonwords than reading ($p = .008$). Additional pairwise comparisons did not identify any further differences ($p \geq .227$).

Table 3.2 demonstrates that nonword error responses dominated output and that there were comparatively few lexical error responses across the group (approximately 17% of responses were lexical errors). No single form of lexical error was particularly dominant across the group and individual variation was evident. For example, p2 produced greater proportions of non-responses in repetition (23%) than reading (6%) or naming (14%). His BDAE auditory comprehension percentile score of 6.5 suggests that he has particular difficulty in processing auditory information, which in repetition manifests as insufficient activation to support response production. However, p10 presents with a similar auditory comprehension deficit (BDAE percentile score of 3) but does not produce any non-responses; therefore, it is unclear why this pattern is observed. Participants p7 and p9 produced higher numbers of unrelated lexical errors in picture naming than in repetition or reading, suggesting that lexical selection errors were more likely in naming for these participants; however, this pattern was not evident in the remaining 8 participants. Overall, circumlocutory responses were no more common in naming versus repetition or reading, apart from participants p5 (22 circumlocutions in response to pictures) and p7 (7 circumlocutions), with no circumlocutions produced in repetition or reading. Both p5 and p7 produced fewer nonwords in picture naming versus repetition/reading, suggesting that the presence of phonological material was more likely to result in an attempted, but not necessarily correct, production.

Table 3.2: The number and (percentage %) of correct responses, nonwords and other error types produced by each participant across repetition, reading and naming.

		Correct	Nonwords	Semantic	Formal	Mixed	Circum.*	Unrelated	Non-response
p1	Repetition	30 (47)	25 (39)	0 (0)	6 (9)	1 (1.5)	0 (0)	1 (1.5)	1 (1.5)
	Reading	38 (59)	21 (33)	0 (0)	2 (3)	1 (1.5)	0 (0)	1 (1.5)	1 (1.5)
	Naming	46 (71)	9 (14)	4 (6)	5 (8)	0 (0)	0 (0)	0 (0)	0 (0)
p2	Repetition	18 (28)	18 (28)	0 (0)	6 (9)	1 (1.5)	0 (0)	6 (9)	15 (23)
	Reading	22 (34)	26 (41)	0 (0)	9 (14)	1 (1.5)	0 (0)	2 (3)	4 (6)
	Naming	28 (43)	15 (23)	5 (8)	2 (3)	0 (0)	5 (8)	0 (0)	9 (14)
p3	Repetition	32 (50)	16 (25)	0 (0)	2 (3)	1 (1.5)	0 (0)	1 (1.5)	12 (19)
	Reading	20 (31)	39 (61)	0 (0)	5 (8)	0 (0)	0 (0)	0 (0)	0 (0)
	Naming	31 (48)	22 (35)	3 (5)	7 (11)	0 (0)	0 (0)	0 (0)	1 (1.5)
p4	Repetition	32 (50)	22 (34)	1 (1.5)	6 (9)	1 (1.5)	0 (0)	2 (3)	0 (0)
	Reading	6 (9)	45 (70)	0 (0)	10 (16)	0 (0)	0 (0)	3 (5)	0 (0)
	Naming	16 (25)	29 (45)	4 (6)	6 (9)	1 (1.5)	0 (0)	7 (11)	1 (1.5)
p5	Repetition	5 (8)	57 (89)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.5)	1 (1.5)
	Reading	20 (31)	32 (50)	1 (1.5)	10 (16)	1 (1.5)	0 (0)	0 (0)	0 (0)
	Naming	12 (19)	15 (23)	3 (5)	5 (8)	0 (0)	22 (34)	0 (0)	7 (11)
p6	Repetition	17 (27)	36 (57)	0 (0)	5 (8)	1 (1.5)	1 (1.5)	4 (6)	0 (0)
	Reading	11 (18)	44 (69)	0 (0)	8 (12.5)	0 (0)	0 (0)	1 (1.5)	0 (0)
	Naming	21 (33)	33 (52)	3 (5)	4 (6)	0 (0)	1 (1.5)	1 (1.5)	1 (1.5)
p7	Repetition	4 (6)	50 (78)	0 (0)	2 (3)	0 (0)	0 (0)	3 (5)	5 (8)
	Reading	9 (14)	49 (77)	1 (1.5)	3 (5)	1 (1.5)	0 (0)	1 (1.5)	0 (0)
	Naming	11 (18)	20 (31)	2 (3)	5 (8)	1 (1.5)	7 (11)	11 (18)	7 (11)
p8	Repetition	4 (6)	44 (69)	0 (0)	8 (12.5)	0 (0)	0 (0)	8 (12.5)	0 (0)
	Reading	7 (11)	51 (80)	0 (0)	6 (9)	0 (0)	0 (0)	0 (0)	0 (0)
	Naming	9 (14)	41 (64)	3 (5)	7 (11)	0 (0)	1 (1.5)	3 (5)	0 (0)
p9	Repetition	4 (6)	51 (79)	0 (0)	3 (5)	0 (0)	0 (0)	6 (9)	0 (0)
	Reading	2 (3)	54 (84)	0 (0)	5 (8)	0 (0)	0 (0)	3 (5)	0 (0)
	Naming	7 (11)	37 (58)	2 (3)	4 (6)	0 (0)	0 (0)	14 (22)	0 (0)
p10	Repetition	1 (1.5)	63 (98)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Reading	11 (18)	50 (78)	0 (0)	2 (3)	0 (0)	0 (0)	0 (0)	1 (1.5)
	Naming	2 (3)	61 (95)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.5)

*Circum. = circumlocution.

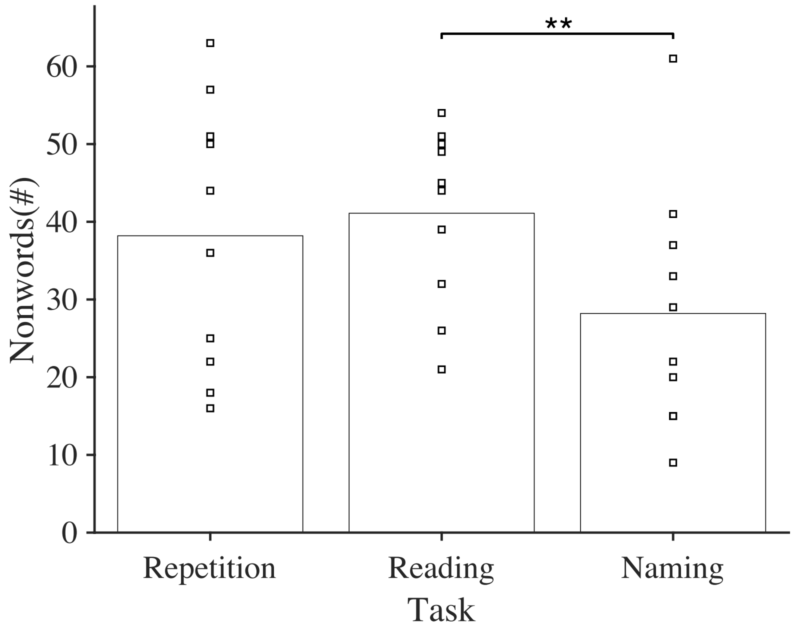


Figure 3.1: Nonword Production in Repetition, Reading and Naming. Bars represent the mean number of nonword responses in each task and individual markers indicate participant nonword numbers

3.4.2 Phonological accuracy of nonwords

3.4.2.1 Observed phonological accuracy

The accuracy of all nonword errors was measured using the Phonological Overlap Index (POI) calculation, thereby assigning values between 0 and 1 to all nonwords, with a value of one reflecting complete phonological overlap between a nonword and target word pair. A repeated measures ANOVA was used to compare average POIs across the three output tasks. The ANOVA identified a significant effect of task on phonological accuracy ($F(2, 18) = 5.665$, $p = .012$, $\eta p^2 = .386$, see Figure 3.2) with post-hoc, Bonferonni corrected, pairwise comparisons identifying that picture naming was less phonologically accurate than reading ($p = .014$). Repetition elicited marginally greater accuracy than naming ($p = .093$).

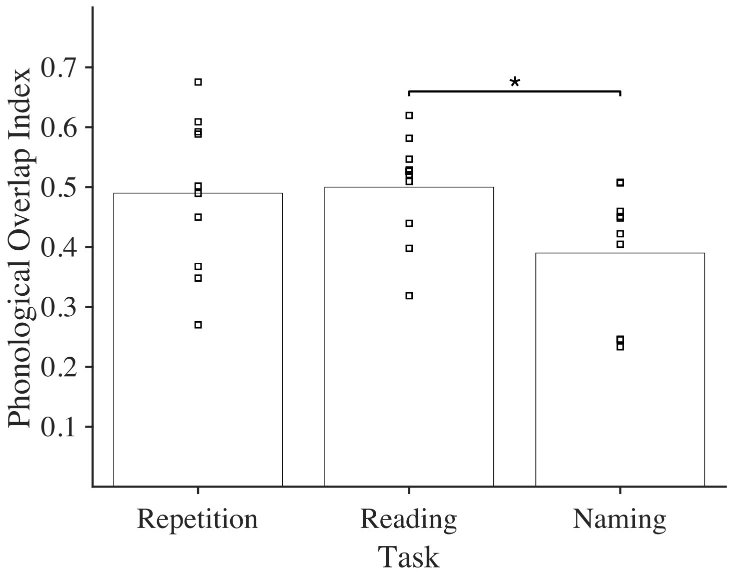


Figure 3.2: Phonological Overlap Index in repetition, reading and naming. Bar chart displays mean Phonological Overlap Index (POI) of nonword errors in each production task. Individual markers represent participant POI means.

For each participant the average POI was calculated for all nonwords in each separate production task and compared against a chance value of phonological accuracy using a bootstrapping procedure. In repetition all ten individuals produced nonwords that contained greater degrees of target phonology than predicted by chance (POI $\bar{x} \geq 0.270$, $p \leq .002$; see Figure 3.3a). The same pattern was observed in reading (POI $\bar{x} \geq 0.318$, $p \leq .001$; see Figure 3.3b). In picture naming, p4 produced target phonology at chance levels (POI $\bar{x} = 0.245$, $p = 0.54$; see Figure 3.3c). The remaining nine individuals produced target phonology at greater than the chance prediction (POI $\bar{x} \geq 0.247$, $p \leq .035$; see Figure 3.3c).

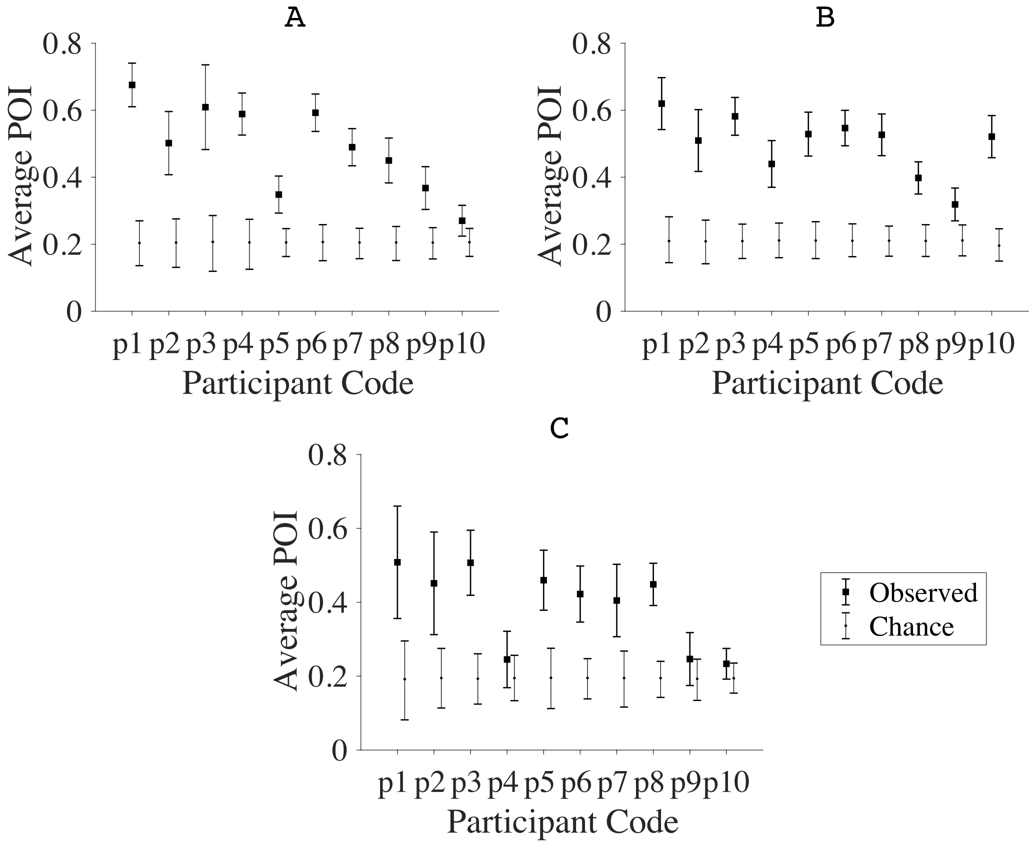


Figure 3.3: Participant Phonological Overlap Index vs. chance Phonological Overlap Index for nonwords produced in repetition (A), reading (B) and picture naming (C). Error bars indicate 95% confidence intervals.

3.4.2.2 Accuracy distributions

The Shapiro Wilk test was used to examine whether nonword accuracy (POI) spread conformed to a normal distribution, thereby suggesting a single phonological locus of nonword error. The POI distributions exhibited by seven individuals (p1, 2, 3, 5, 6, 7, 8) either conformed to a normal distribution ($p \leq 0.077$) or followed a negative skew, indicating a tendency towards higher target overlap (a greater proportion of nonwords observed above the mean, see Table 3.3 marked▲). The POI accuracy distribution for p4 did not follow a normal distribution in naming ($p = 0.013$, skewness = 0.529, Figure 3.4D); p9 also exhibited a normality violation in naming ($p = 0.003$, skewness = 0.721, Figure 3.4D); p10 violated the normal distribution in repetition ($p = 0.005$, skewness = 0.620, Figure 3.4B) and in naming ($p = 0.004$, skewness = 0.258, Figure 3.4A). Visual inspection of these histograms indicates a heavy skew towards lower phonological accuracy with a graded increase in accuracy from zero, rather than a bimodal distribution (see Figure 3.4).

Table 3.3: p statistics from Shapiro Wilk normality test of POI distribution.

	Repetition	Reading	Naming
p1	.092	.204	.294
p2	.757	.090	.190
p3	.244	.263	.608
p4	.155	.187	.013●
p5	.115	.136	.452
p6	.020▲	.153	.625
p7	.067	.039▲	.077
p8	.217	.761	.663
p9	.109	.082	.003●
p10	.005 ●	.267	.004●

Symbol Key: ▲ negative skew (majority of POIs fell above the mean); •positive skew.

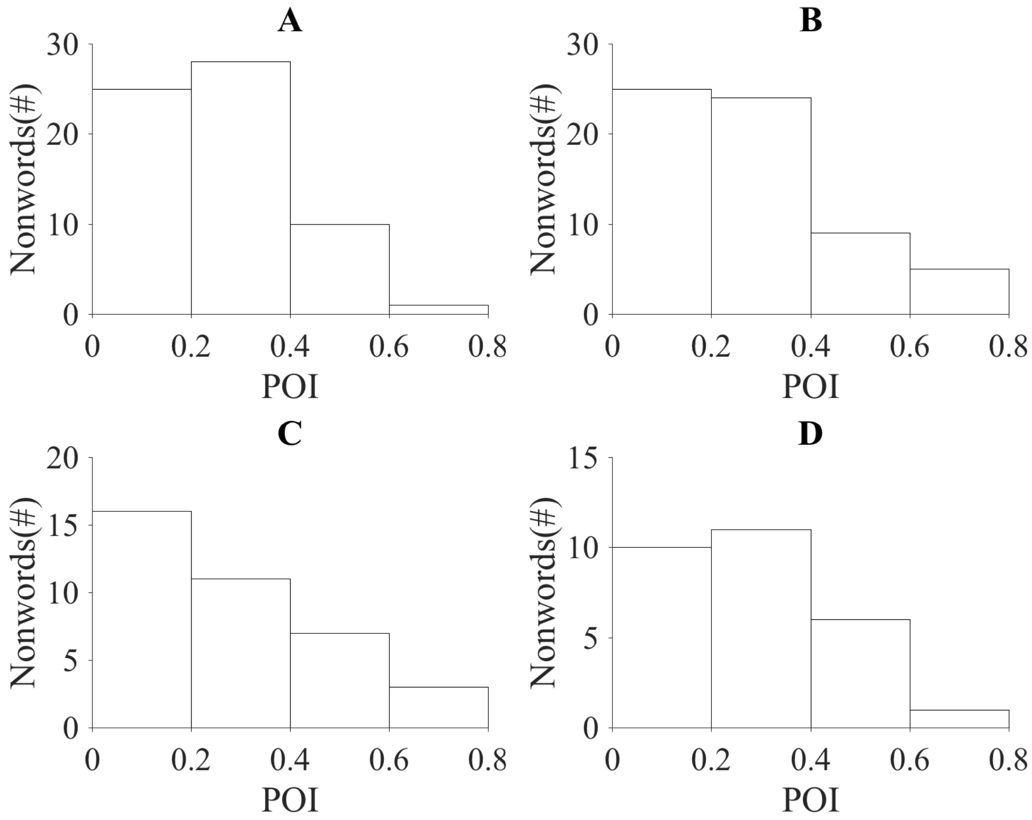


Figure 3.4: Phonological Overlap Index distributions when normality violated. (A) p10 naming, (B) p10 repetition, (C), p9 naming, (D) p4 naming.

3.4.3 Phoneme frequency distributions

The Kolmogorov Smirnov Two-sample test (KS2) was used to identify whether the nonword phoneme inventory of each individual participant conformed to English norms (Dene, 1963). To ensure sufficient data for this analysis, nonword phonemes were collapsed across production task and overall prevalence of each phoneme was calculated as a percentage. The KS2 test demonstrated that nine out of ten individuals distributed phonemes in line with the expected normative pattern ($p \geq 0.076$; see Table 3.4 for full results). Figure 3.5 depicts the phoneme frequency distributions for each Jargon participant, with box plots reflecting negatively skewed distributions similar to that of English norms.

Table 3.4: Z statistic and p value from Kolmogorov Smirnov two (KS2) test comparing normative and individual nonword phoneme frequency distributions.

	KS Z[a]	*P*
p1	1.173	0.128
p2	1.386	0.043
p3	0.853	0.461
p4	0.959	0.316
p5	1.279	0.076
p6	0.853	0.461
p7	1.173	0.128
p8	1.279	0.076
p9	1.173	0.128
p10	0.853	0.461

KS Z[a] = Kolmogorov Smirnov 2 test Z statistic.

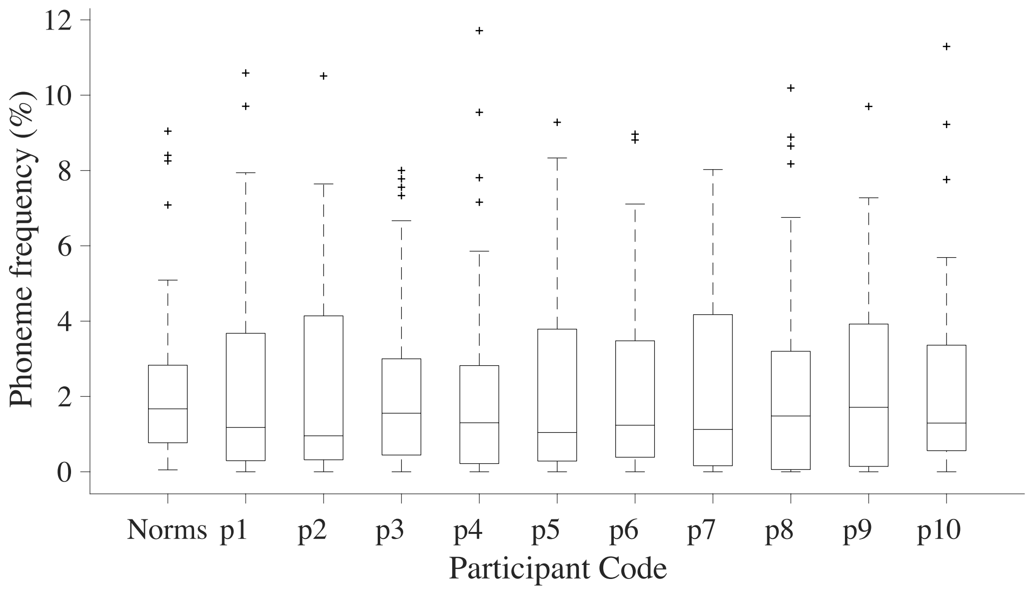


Figure 3.5: Phoneme frequency distributions for English norms and participants.

3.5 ***Discussion***

3.5.1 Group error prevalence

This study examined the nonword error patterns produced on single word repetition, reading and picture naming tasks in a group of ten people with Jargon aphasia. Current hypotheses propose that nonwords arise through either a single, phonological source or a dual impairment in lexical and phonological processing. A single phonological source predicts that a similar proportion of nonword errors will be produced across the different production tasks, since the phonological encoding requirements are similar (Olson et al., 2007; 2015). A dual source predicts that a greater proportion of nonword errors will be observed in naming than in reading and repetition, as naming weighs more heavily on lexical processing and cannot utilise sub-lexical processing to support production in the event of deficient lexical information (Coltheart et al., 1993; Moses et al., 2004; Nozari, Kitteridge, Dell, & Schwartz, 2010; Olson et al., 2015). Results from the current study did not clearly conform to either of these patterns. Instead there were higher numbers of nonword errors in reading (statistically) and repetition (numerically) than in naming. Nevertheless, this result aligns best with the single phonological source hypothesis, in that more nonwords were produced in tasks with greater focus on phonological processing. Tasks which increased focus on lexical-semantic processing reduced the likelihood of nonword production. These results conflict with previous single case studies which have identified greater neologistic or error production impairments in Jargon naming (Ackerman & Ellis, 2007; Moses et al., 2004; Corbett et al., 2008) and are inconsistent with patterns observed in the aphasia population generally where repetition tends to be more accurate than naming (Nozari et al., 2010). A significant proportion of this evidence comes from computational modelling studies which have described nonword production patterns primarily in naming and attempted to explain error patterns in other production tasks based on the naming models. The fewer numbers of nonword errors produced to tasks involving non-lexical processing components (e.g. repetition) are accounted for by recruitment of nonlexical processing routes which make use of surface word graphemes/phonemes and which can compensate for weak lexical route processing and bolster production accuracy (Dell et al., 1997; Hanley, Dell, Kay, & Baron, 2004; Nozari et al., 2010). Picture naming, where nonlexical information is not available, lacks this additional boost and so is more likely to elicit errors. Closer examination of the cases within computational modelling studies (e.g. Nozari et al., 2010) demonstrate that individuals with poor language comprehension abilities such as that observed in Jargon aphasia, for example, those with Wernicke's aphasia, do not clearly conform to this dual route prediction and that these individuals produce error rates that are more equally balanced across the different production tasks; a pattern that is consistent with a subset of participants in the current group.

However, 4 participants (p1, p5, p7 and p9) produced more nonwords on both repetition and reading than in naming (similar trends were also observed in 3 other individuals, see Table 2), suggesting that dual route processing is not consistently operational in this sub set of individuals. The pattern exhibited by these 4 participants can, however, still be explained within existing frameworks of naming and repetition. Studies examining the balance between lexical and nonlexical processing in tasks such as reading and repetition have indicated differential routing patterns dependent on the person's ability to comprehend and recognise words (Nozari & Dell, 2013). Individuals with greater lexical-semantic comprehension abilities favour the lexical processing route and make use of this for accomplishing tasks such as auditory repetition. People whose lexical comprehension and recognition are more severely impaired are pushed towards nonlexical processing as an alternative, since subsequent lexically motivated processing cannot proceed without sufficient lexical-word activation. All individuals in the current study had a diagnosis of Wernicke's aphasia and, consequently, severe impairments in analysing and processing input phonology, and comorbid impairments in lexical-semantic processing and comprehension (Robson, Sage, & Lambon Ralph, 2012). In the current group, it is likely that impairments in language comprehension limit participant ability to access and use the lexical-semantic pathway to support production, thereby increasing reliance on surface level (nonlexical) information in tasks where this is possible (Nozari & Dell, 2013). Additionally, the ability to decipher input phonology is significantly impaired in Wernicke's aphasia. Therefore, activation of target phonology from the nonlexical route will be severely disrupted, which will increase the likelihood of observing a nonword. This pattern of processing can explain the greater number of nonword errors observed in repetition/reading in comparison to picture naming.

3.5.2 Case series analyses

The single source interpretation is challenged by the finding that the phonological accuracy of nonword errors (target-error overlap, measured by the POI) was *lower* in naming than in reading and repetition. This could be taken as evidence for an additional lexical impairment contributing to nonwords either through complete lexical retrieval failure and idiosyncratic phonology generation or through lexical retrieval errors which are subsequently phonologically distorted (compound errors). However, further analysis of the phonological content of nonword errors argues against these interpretations. The phonological overlap between nonword errors and targets was compared to that expected by chance. Above chance level phonological accuracy (e.g. village, /lɪvɪdʒ/) is unlikely without adequate access to the lexical representation of a word, whereas phonological accuracy at the chance level would occur following lexical error or lexical retrieval failure (Godbold et al., 2013; Olson et al., 2007; Robson et al., 2003). This is particularly the case in naming where only a lexical processing route is available. Although this analysis confirmed severe levels of impairment – on average nonwords contained less than half of the targets phonemes (see Figure 3.2) – the phonological accuracy of nonword errors was above chance in all participants in almost all tasks, supporting the hypothesis that accurate lexical information is available. This was further supported by analysis of the distribution of the POI of nonword errors. It has been proposed that a single phonological nonword error source will produce a normal distribution of phonological accuracy in nonwords whereas a dual lexical-phonological source will produce a bimodal distribution with a large proportion of errors with very limited target overlap (Olson et al., 2007; 2015; Schwartz et al., 2004). The majority of POI distributions in the current study adhered to a normal distribution or were negatively skewed, a trend also noted in existing Jargon case studies (Olson et al., 2007; 2015), suggesting that lexically mediated nonword errors were scarcely produced. In addition to these analyses, qualitative interpretation of participant data demonstrated little to no evidence of compound errors, i.e. moderate phonological disruption of semantic errors, hypothesised as reflecting a lack of lexical influence (Olson et al., 2015). Together these results do not indicate a significant lexical contribution to nonword errors in Jargon aphasia. Instead it is interpreted that greater phonological accuracy in reading and repetition than in naming indicates some ability to use input phonological information to support phonological encoding. This pattern is compatible with the earlier interpretation that tasks of repetition and reading can be accomplished either by lexical-phonological processing when word recognition has triggered at least partially correct phonological information, or nonlexical processing which maps input – output phonology, again, with some degree of success.

3.5.3 Exception cases

Observation of the case series highlighted a number of notable exceptions. Participant 4's nonword phonological accuracy in naming was not significantly different from chance, and the corresponding POI distribution was non-normally distributed. POI distribution normality violations also occurred for two other participants – p9 in naming, and p10 in naming and repetition. It is possible that these individuals have more significant lexical processing impairment than the other participants and that this impairment contributed to nonword production. The existence of lexically mediated errors, possessing very limited accurate phonology, is expected to co-occur alongside a group of errors containing more moderate degrees of target phonology, together eliciting a bimodal accuracy distribution (Olson et al., 2007; 2015; Schwartz et al., 2004). Bimodal distributions were not observed in these participants. Instead, positively skewed histograms (see Figure 3.4) were observed, indicating that, for these particular individuals, nonword accuracy was heavily weighted towards lower accuracy production. This trend indicates very severe phonological encoding impairments, particularly in naming where no sub-lexical support was available. Participant 10 displayed a POI normality violation in repetition, alongside a low POI average score for this task (0.27, see Figure 3.3a). Individuals with Wernicke's aphasia have well documented auditory and input phonological processing impairments which are associated with their language comprehension impairment (Robson, et al., 2012; Robson, Pilkington, Evans, DeLuca, & Keidel, 2017). Participant 10 displayed the most severe language comprehension impairment indicating considerable auditory processing difficulties and a reduced ability to use phonological input information to boost production in repetition via lexical or nonlexical processing.

3.5.4 Jargon phonological inventories

Although these three cases presented with the greatest degree of nonword production impairment, the majority of participants in the current study presented with severe Jargon aphasia. It has been proposed that such individuals may suffer from a *distorted* phonological system due to long standing nonword production warping phonological representations and /or their links with the lexical system (Eaton et al., 2010; Moses et al., 2004). This was explored by analysing the occurrence of phoneme segments within nonwords to determine whether nonword phoneme frequency distributions pertain to the typical phoneme distributions observed in English, thus indicating whether the phonological system in Jargon aphasia operates in line with its typical numerical distributional properties. All but one participant (p2) in the current study produced phonological segments in line with that expected in English, suggesting that, for the most part, the phonological system maintains its typical organisation and structure. This is contrary to results reported in previous studies, where evidence of idiosyncratic or default phonological useage is documented (Eaton et al., 2010; Moses et al., 2004). However, the current data were sampled at a single time point within what is typically a prolonged recovery trajectory, when the majority of the group were not classified as chronic. Therefore, current results cannot exclude that long-standing nonword production in Jargon aphasia may self-reinforce deviant phonological useage and alter the rates at which specific phonological segments reside. For example, participants p5 and p8 are statistically borderline in how their phonological distribution adhered to the normal observed phoneme useage, and p4 demonstrates over representation of a phonological segment (see Figure 3.5), suggesting that their phonological selection may be in the early stages of distortion and may evolve into an idiosyncratic system. Therefore, longitudinal analyses may be more suited to investigating this hypothesis.

3.6 ***Conclusion***

This study investigated the degree to which lexical impairment contributed to the production of nonword errors in Jargon aphasia by analysing the number and content of nonword errors produced during repetition, reading and naming in a case series of 10 individuals with neologistic production. Overall, the phonological inventories of the group adhered to English norms indicating that Jargon nonword production arises through a phonological system that maintains the typical phonological organisation and suggests that production is constrained by lexical-phonological processing. The phonological content of nonwords indicated that some accurate lexical information is available for the majority of individuals with Jargon aphasia during word production. However, impairments in lexical recognition and processing lead to reliance on phonological information to support production, thereby increasing the number of nonwords. Picture naming, which does not involve the presentation of phonological material, maximises lexical processing which reduces the likelihood of observing a nonword. These results demonstrate that tasks which maximise phonological processing demands increase the amount of Jargon and indicate that Jargon nonword error production is phonologically mediated.

Chapter 4. When does lexical availability influence phonology? Evidence from Jargon reading and repetition.

Emma Pilkington[a*], Karen Sage[b], Douglas Saddy[a], and Holly Robson[a]

[a]*School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK.*
[b]*Department of Allied Health Professions, Sheffield Hallam University, Sheffield, UK.*
**School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK, RG6 7BE. E.c.pilkington@pgr.reading.ac.uk*

Chapter 4 information

This chapter was accepted for publication in the *Journal of Language, Cognition and Neuroscience* on 15/09/2019. This study includes participants who were recruited by both Emma Pilkington and Holly Robson. All data were collected by Emma Pilkington as part of PhD completion at the University of Reading. Ethical approval for this study was obtained from the University of Reading School of Psychology and Clinical Language Sciences Ethics Board (see Appendices 8.2, 8.3, 8.4, 8.5).

Authorship statement

E. Pilkington: conceptualisation; methodology; resources (recruitment and data collection), curation and analysis; manuscript preparation; visualisation; funding acquisition.
K. Sage: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
D. Saddy: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
H. Robson: conceptualisation; methodology; resources (participant recruitment); manuscript review and editing; supervision; funding acquisition.

4.1 *Abstract*

Jargon aphasia is a language disorder characterised by phonological and nonword errors. Errors are thought to arise when target segments are insufficiently activated, allowing non-target or recently used phonology to intrude. Words which are more frequent and familiar reside with greater degrees of activation and therefore should be less susceptible to error. The current study tested this hypothesis in a group of ten people with Jargon aphasia using single word repetition and reading aloud. Each task had two lexicality conditions, one high and one low lexical availability word set. Measures of nonword quantity, phonological accuracy and perseveration were used in group and case series analyses. Results demonstrated that fewer nonwords were produced when lexical availability was greater. However, lexicality effects on phonological accuracy and perseveration were only observed in repetition in a sub-group of moderately impaired individuals, demonstrating that lexical information does not consistently influence phonological processing in Jargon aphasia.

4.2 ***Introduction***

4.2.1 Jargon aphasia production

Jargon aphasia is a form of acquired language impairment characterised by nonsensical spoken production post brain damage (Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, 1980; Hillis, 2007). The semantic form of Jargon aphasia is associated with production of real word errors which are often semantically unrelated to the context or target word. Such errors are thought to occur secondary to lexical-semantic impairment, impacting word selection and rendering production incomprehensible (Brown, 1981; Marshall, Chiat, Robson & Pring, 1996; Marshall, Pring, Chiat & Robson, 1996). This contrasts with the phonological form of Jargon aphasia which is characterised by nonword error production. This study is concerned with phonological Jargon aphasia (referred to as Jargon aphasia from hereafter). Nonword errors occur when phonological segment errors contaminate a word, for example, the word *'winter'* read aloud as /wɪnstə/. The degree of phonological segment error within nonwords is variable and can affect all or most of the phonemes within a word, for example, the word 'ocean' being read aloud as /senɪvɪtʃ/. The phonological accuracy within nonwords is thought to vary with the amount of lexical-phonological constraint, with errors such as /senɪvɪtʃ/ arising from significant lexical-phonological disruption and nonwords such as /wɪnstə/ occurring with much milder disruption to segment selection (Marshall, 2006; Olson, Romani and Halloran, 2015; Schwartz, Wilshire, Gagnon and Polansky, 2004). Attempts to elicit nonword production errors from healthy controls succeed in generating slip-of-the tongue like error, but the severity and quantity observed in Jargon aphasia is unmatched (Baars, Motley & MacKay, 1975; Dell & Reich, 1981; Schwartz, Saffran, Bloch & Dell, 1994).

In Jargon aphasia nonwords occur in abundance. However, as people produce Jargon, they often make little or no effort to correct their erroneous production (Alajouanine, 1956; Kertesz & Benson, 1970). This pattern of production has been partly linked to impaired self-awareness and reduced monitoring of self-generated speech. Kinsbourne and Warrington (1963) report two individuals with copious errorful speech output who, when asked, stated no awareness of their Jargon impairment. Marshall, Robson, Pring and Chiat (1998) document that RMM, a lady with severe Jargon production, spoke fluently and produced highly errorful and incomprehensible speech, yet made little attempt to self-correct. People with Jargon aphasia often present with impairments in auditory processing and comprehension, which have been linked in some cases to the impaired ability to monitor and detect errors in production (Purcell, Lambon-Ralph, & Sage, 2018; Sampson & Faroqi-Shah, 2011). This is consistent with the lesion profile in Jargon aphasia, which commonly includes the primary and secondary auditory cortices of the left superior temporal gyrus (Kertesz & Benson, 1970; Pilkington et al., 2017) which are involved in acoustic analysis and the extraction of phonetic and phonological information (Mesgarani, Cheung, Johnson, & Chang, 2014). Many individuals with Jargon aphasia present with a wider language profile of Wernicke's aphasia, a condition associated with a similar lesion profile (Robson, Specht, Beaumont, Parkes, Sage, Lambon Ralph & Zahn, 2017), and established auditory processing impairment (Robson, Grube, Lambon Ralph, Griffiths & Sage, 2013). However, a number of Jargon case reports identify people with relatively persevered auditory processing ability alongside persistent failure to monitor or inhibit their own errors (Kohn, Smith & Alexander, 1996; Marshall et al., 1998; Olson et al., 2015; Robinson, Butterworth, & Cipolotti, 2015) and, therefore, auditory processing impairments do not appear to be a necessary feature of Jargon aphasia.

In addition to auditory processing and perception regions, lesion profiles – commonly involving the left posterior superior temporal gyrus and supramarginal gyrus – also implicate retrieval of phonological sequences and word forms (Binder, 2017; Buchsbaum et al., 2011; Hillis, Boatman, Hart, & Gordon, 1999; Kertesz, 1981; Kertesz & Benson, 1970; Pilkington et al., 2017). Behavioural data align with the lesion profile, in that error production patterns indicate a strong role of phonological processing in nonword generation. Analyses of nonword phonology demonstrate that both high and low accuracy nonwords reflect the correctly selected word representation which is disrupted during phonological segment processing, indicated by greater than chance phonological accuracy (Buckingham & Kertesz, 1974; Kohn, Smith, & Alexander, 1996; Olson, Halloran, & Romani, 2015; Olson, Romani, & Halloran, 2007; Pilkington et al., 2017; Robson, Pring, Marshall, & Chiat, 2003). Perseveration – the repeated use of error phonemes across consecutive responses – is also frequently observed in Jargon aphasia and usually affects phonological segment production.

The patterns of perseveration observed in Jargon aphasia suggest that target words and/or phonology are insufficiently activated because parts of the language network are damaged, and this damage impedes activation flow within the network and compromises production. This is referred to as the activation deficit account, and by this theory damage affecting word selection processes will generate word perseverations whereas damage to phonological representations will more likely generate phoneme perseverations (Moses, Sheard & Nickels, 2007; Stark, 2007). In Jargon aphasia, which is associated with phonological impairment, weakly activated phonological segments will be less able to override residual activation at previously used segments and a phonological perseveration will be produced (Martin and Dell, 2007; Hirsh, 1998). Interactive two-step models of lexical processing have evaluated this activation deficit account in large groups of people who produce nonword errors, demonstrating that insufficiently activated target phonological segments underpin nonword production and can arise as a consequence of insufficient semantic-conceptual, lexical or phonological activation (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000; Martin & Dell, 2007). Intrinsic noise or residual activation at recently used segments, if greater than the impoverished target activation, will override target segments and prevail for production (Cohen & Dehaene, 1998; Dell, Martin, & Schwartz, 2007; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Martin & Dell, 2007; Moses, Nickels, & Sheard, 2004; O'Connell, 1981). Decreasing the amount of semantic or word level activation in computational models generates greater numbers of nonword and perseverative errors and the generated error patterns conform to data observed in large groups of people with aphasia, including people who perseverate (Dell, Martin, & Schwartz, 2007; Martin & Dell, 2007), suggesting that lexical-semantic activation influences phonological processing and nonword error production in people with aphasia. Perseveration occurs in greater amounts on tasks of single word production (Buckingham, 1990; Buckingham & Buckingham, 2011) and is more common in individuals who present with more severe production impairments. However, not all persons with Jargon aphasia exhibit perseveration (Pilkington et al., 2017). Kohn, Smith and Alexander (1996) propose that perseveration is a diagnostic indicator of the underlying deficit, suggesting that perseveration occurs when lexical-phonological representations have been damaged or lost such that activation cannot transfer within the lexical network, meaning processing is based primairly on prior production. On the contrary, Kohn, Smith and Alexander (1996) suggest that people who have impaired access to presevered representations are unlikely to perseverate because they can make use of alternate, neighnouring respresentations to support production. There are few studies exmaining such patterns in Jargon aphasia, and more work explroing perseveration is important to better understand the Jargon impairment. There are few studies examining such patterns in Jargon aphasia and more work exploring perseveration is required to better understand the underlying mechanisms. Perseveration is also observed in other neurological conditions including Parkinson's disease, dementia and other stroke profiles and is often associated with frontal lobe disturbance or sub-cortical damage involving the basal ganglia or the thalamus (Bayles, Tomoeda, Kaszniak, Stern & Eagans, 1985; Pekkala, Albert, Spiro, & Erkinjuntti, 2008; Robin & Schienberg, 1990; Sandson & Albert, 1984; 1987). Perseveration in these conditions has been associated with a range of executive functioning impairments including failed inhibition of a previous response or a thought process, impaired attention, and working memory deficits (Fischer-Baum & Rapp, 2012; Frankell, Penn, & Ormond-Brown, 2010; Papagno & Basso, 1996; Purcell et al., 2018; Robinson, et al., 2015; Santo-Pietro & Rigrodsky, 1980; Yamadori, 1981). The extent to which these factors influence the Jargon aphasia impairment is yet to be established.

The Jargon aphasia label is not a traditional subtype of aphasia and is not found within diagnostic assessment batteries, therefore, identifying Jargon aphasia is not straightforward. Traditional accounts of Jargon aphasia describe nonword error patterns within connected speech samples (Buckingham, 1977; Buckingham & Kertesz, 1974; Kertesz & Benson, 1970; Kinsbourne & Warrington, 1963), and thus, application of the Jargon aphasia label has typically been adopted when reporting individuals who produce high proportions of nonword error within connected speech (Brown, 1981; Marshall, 2006). However, the most consistent diagnostic feature reported in Jargon aphasia studies is high numbers of nonword error production (Bose, 2013; Eaton, Marshall & Pring, 2011; Kohn, Smith & Alexander, 1996; Marshall et al., 1998; Olson, et al., 2015). Single word production tasks are an ideal way to study nonwords because the target-nonword relationship is overt. For example, the nonword response /senɪvɪtʃ/ would be difficult to relate back to its source word, 'ocean' if produced in a connected speech task where the target word ocean was not known to the experimenter. Single word production tasks circumvent this challenge as the target word is pre-defined, which allows for close examination of accuracy at the phonological level. Many existing studies make use of the advantages offered from a single word production paradigm, using picture naming, reading and repetition as probes of nonword production (Bose, 2013; Kohn et al., 1996; Martin & Dell, 2007; Pilkington et al., 2019; Olson et al., 2015; Schwartz et al., 1994; 2004). Repetition and reading offer an advantage over picture naming in that they allow for more flexible manipulation of semantic word properties such as imageability and are not confounded by name agreement.

4.2.2 Lexical influences in reading and repetition

The influence of word level activation over phonological processing has been widely explored in numerous production tasks and it is well documented that words which are lexically less demanding to process (that is more frequent, imageable, concrete or familiar) are named, read, and repeated more efficiently and accurately (Gerhand & Barry, 1998; Hulme et al., 1997; Laszlo & Federmeier, 2007; Monsell, Doyle, & Haggard, 1989; Strain, Patterson, & Seidenberg, 1995; 2002). This effect is generally interpreted as an index of lexical availability; words which are produced more accurately and efficiently are lexically more available and thus require less processing input for production to be achieved. On the other hand, words which are less frequent and have lower imageability are less available at the word level and require greater amounts of processing input or activation for successful production. Although many studies exploring lexicality effects have focused on picture naming, several existing models provide frameworks that explain these lexicality effects when also observed in repetition and reading. Within connectionist frameworks, computational modelling accounts often divide lexical processing into three distinct processes of semantic, lexical and phonological levels, where activation is transferred interactively across these different levels (Dell et al., 1997; Foygel & Dell, 2000). Words which are used more frequently are thought to reside with greater degrees of activation, such that activation spreads more easily and efficiently between levels for words which are highly familiar and frequent, making phonological selection more accurate and production more efficient (Kittredge, Dell, Verkuilen, & Schwartz, 2008). For tasks of repetition and reading, there is an additional nonlexical processing route to account for the surface word processing that can map phonological/graphemic word information to output sounds for production (Dell et al., 2007; Nozari & Dell, 2013). Both single and dual route frameworks demonstrate effects of lexical variables including frequency, familiarity and age of acquisition, demonstrating a clear contribution of lexical information in reading and repetition processing (Nozari, Kittredge, Dell, & Schwartz, 2010). Frameworks that are based on a single interactive model for word production make predictions that align with those presented in dual route computational accounts, since phonology and semantics interact and inform one another and, thus, semantic information and activation exerts influence over phonological selection and constrains production to facilitate production of real word patterns (Patterson, Graham, & Hodges, 1994; Plaut & Kello, 1999). Behavioural studies examining effects of lexical variables in repetition and reading have demonstrated robust effects of variables such as frequency and imageability (Coltheart, Curtis, Atkins & Haller 1993; Coltheart, Rastle, Perry, Langdon & Zeigler 2001, Dell, Martin, & Schwartz, 2007; Hanley & Kay, 1997; McCarthy & Warrington, 1984; Nozari et al., 2010) and this lexicality effect has been replicated in studies of aphasic word repetition and reading (Crisp & Lambon Ralph, 2006; Hanley, Kay, & Edwards, 2002; Hirsh, 1998; Jefferies, Crisp, & Lambon Ralph, 2006). However, people who have Jargon-like aphasia presentations are underrepresented in large scale group studies of aphasia and so it remains unclear whether lexical-semantic information is useful for informing phonological production in participants whose deficits are thought to be predominantly phonological.

There are a small number of studies which focus more specifically on people who have aphasia characterised by phonological impairment. Romani, Galluzzi and Olson (2011) analysed error patterns from six aphasia participants with phonological production deficits on tasks of reading and repetition. They explored whether errors produced by these individuals supported the existence of and contribution from a phonological buffer, indicated by length effects (more probability of phoneme error in longer words) and phoneme position information (phonemes later on in a word were more likely to be errors). Their results demonstrated a lack of buffer-like effects, suggesting that activation of phonemes is supplied and maintained not from a phonological buffer but instead, via the word-lexical representation. These results suggest that phonological production in word repetition and reading is informed by lexical-word level activation. Other examples which include participants with more severe, Jargon-like profiles, provide support for the influence of lexical factors such as frequency and imageability over phonological production, demonstrating that production is more accurate when lexical information is more readily available; indicating that lexical information can positively inform phonological processing and increase accuracy in people with more severe phonological deficits (Gotts, della Rocchetta, & Cipolotti, 2002; Hirsh, 1998). A case series study by Jefferies et al. (2006) describes this effect as reflecting a maximisation of lexical-semantic processing, suggesting that people with specific and significant phonological impairments are inclined to capitalise on other, less impaired, processing components (in this case lexical-semantic information), in an attempt to overcome the phonological impairment. Therefore, enhanced lexicality, frequency and imageability effects are expected from people who present with phonological aphasia (Jefferies et al., 2006; Martin & Saffran, 1997). However, case studies of individuals with phonological aphasia do not consistently evidence effects of lexical availability in tasks of naming, reading and repetition (Ackerman & Ellis, 2010; Corbett, Jefferies & Lambon Ralph, 2008). Nozari and Dell (2013) report on a larger group of people with aphasia and demonstrate that preserved access to lexical representations and word meaning motivate the use of lexical based processing to accomplish repetition production, whereas impairments in lexical-semantic comprehension limit the ability to recognise and understand a word and therefore push processing more towards nonlexical avenues. It is unclear how successfully people with Jargon and phonological impairment can recruit and use lexical processing to support production, especially since access to lexical and semantic representations tends to be impaired (Robson et al., 2017).

4.2.3 Nonlexical influences in reading and repetition

In reading and repetition, it is both possible and probable that surface word information, that is the phonemes and graphemes within a stimulus word, will inform and influence word production processing. The use of these surface features to benefit production is usually referred to as sub-lexical or nonlexical processing. Measuring the influence of these factors is problematic because nonlexical factors such as phonemic and graphemic length co-vary with lexical factors such as frequency and familiarity (Nickels & Howard, 2004). The phonemic and graphemic length of a stimulus word has been shown to impact on processing and production effectiveness in that words which are shorter or contain more frequently used letters have shorter visual fixation periods and are produced or responded to more quickly (Baron & Strawson, 1976; Grainger & Segui, 1990; Rayner & Duffy, 1986; Weekes, 1997). In reports of people who have Jargon aphasia, target words with longer phonemic lengths are associated with lower accuracy responses than target words which contain fewer phonemes (Halpern, 1965; Olson et al., 2007). In a study with ten participants who had Jargon aphasia, Pilkington, Sage, Saddy and Robson (2019) demonstrate that greater numbers of nonword errors are produced in tasks of repetition and reading in comparison to picture naming, suggesting that tasks which place greater emphasis on phonological material and nonlexical processing increase Jargon severity. These results indicate that Jargon production is influenced by phonological processing demands and suggest a strong role of phonological processing in the error generation of Jargon nonwords. Therefore, in exploring the influence of lexical variables over production, nonlexical variables must be accounted for and carefully controlled.

4.2.4 The current study

The current study aims to gather further information about the influence that the lexical system exerts over phonological production, by exploring how differing amounts of lexical activation impact on phonological production in Jargon aphasia. To accomplish this, words which possess inherently different amounts of lexical activation, for example high and low frequency items, were used in tasks of repetition and reading. The phonological content of target words was matched across testing sets to control for phonological processing demands. The primary research hypothesis was that Jargon production would be increasingly impaired when people processed words that were lexically more demanding/less available in comparison to reading/repeating words that were lexically less demanding/more available. Ten participants with Jargon aphasia completed the repetition and reading tasks. Their responses were quantified by number of nonword errors produced, phonological accuracy within nonwords and phoneme perseveration within nonwords. Jargon aphasia is associated with impairments in auditory comprehension and auditory-phonological analysis (Robson, Grube, Lambon Ralph, Griffiths, & Sage, 2013), such that lexical comprehension and recognition tends to be poorer in auditory tasks in comparison to written tasks. Therefore, the secondary research hypothesis was that greater effects of lexical availability were expected in word reading, since better lexical-semantic comprehension and access is known to maximise lexical mechanisms and minimise nonlexical processing (Nozari & Dell, 2013). In Jargon aphasia repetition, poorer lexical comprehension should push processing more towards nonlexical avenues, which would elicit fewer lexical effects in word repetition.

4.3 *Materials and methods*

4.3.1 Participants

Ethical approval for this study was gained from the School of Psychology and Clinical Language Sciences Research Ethics Committee at the University of Reading (project approval code: 2016-064-HR). The current study details ten individuals (three female; age $\bar{x}$ = 73 years, σ = 11.3; time post stroke (months, $\bar{x}$ = 35, σ = 20.75, see Table 4.1) who were identified as having Jargon aphasia according to their language profile on The Boston Diagnostic Aphasia Examination short form (BDAE, Goodglass, Kaplan and Barresi, 2001) and their single word production error profile. The BDAE identified Jargon-like behavioural profiles characterised by impaired auditory comprehension, poor repetition and fluent spoken production (see Figure 4.1). Participants E and J display reduced fluency in relation to that typically reported in people with Jargon aphasia (see Figure 4.1). Both participants produced connected speech with output comprising phrases of four or five items (including words and nonwords) and their remaining language profiles (impaired auditory comprehension and repetition) align with the typical Jargon profile. Furthermore, on single word production tasks their dominant error type is nonwords (see Figure 4.2) and therefore they conform to the Jargon aphasia profile. Participant A is the most accurate and scores highly on the repetition subtests, out-performing the rest of the group and deviating from the typical Jargon aphasia profile (see Figure 4.1). His fluency and auditory comprehension align with the typical Jargon profile and his dominant error type is nonwords (see Figure 4.2) hence he was identified as mild Jargon aphasia and included in the current study. On the single word production tasks, all ten participants produced nonword errors more than any other error form, indicating Jargon aphasia (see Figure 4.2). Participants are ranked by the quantity of nonwords produced on experimental testing and are presented in this order throughout, with participant A producing fewest errors and participant J producing the greatest number of nonwords. All participants gave informed consent to participate in the current study.

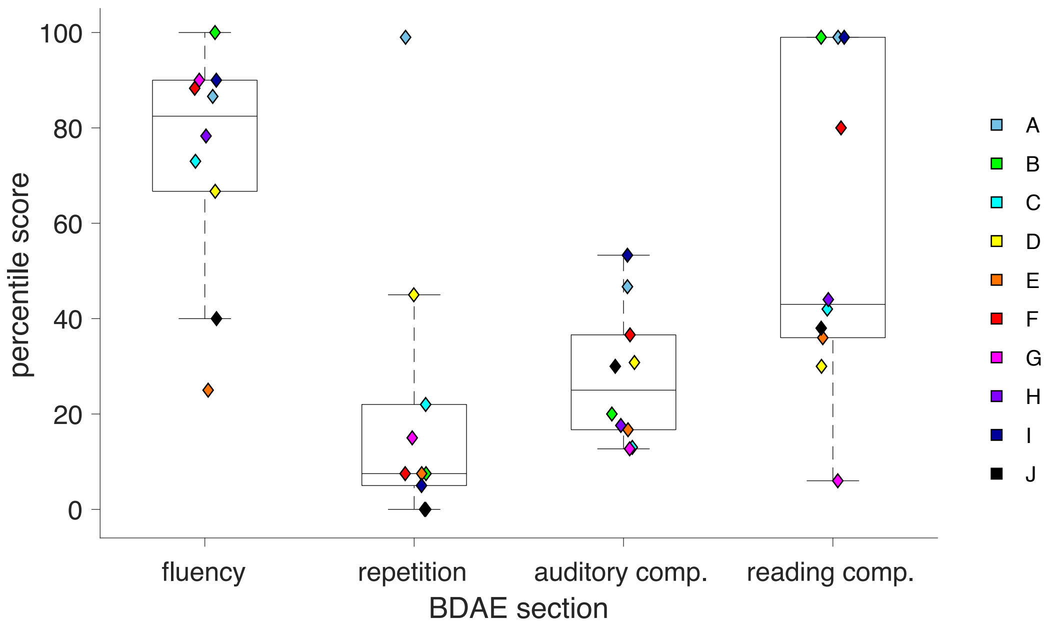


Figure 4.1: Boston Diagnostic Aphasia Evaluation (BDAE) Speech Profiles for Jargon participants, Participant code and colour presented in key; comp. = comprehension.

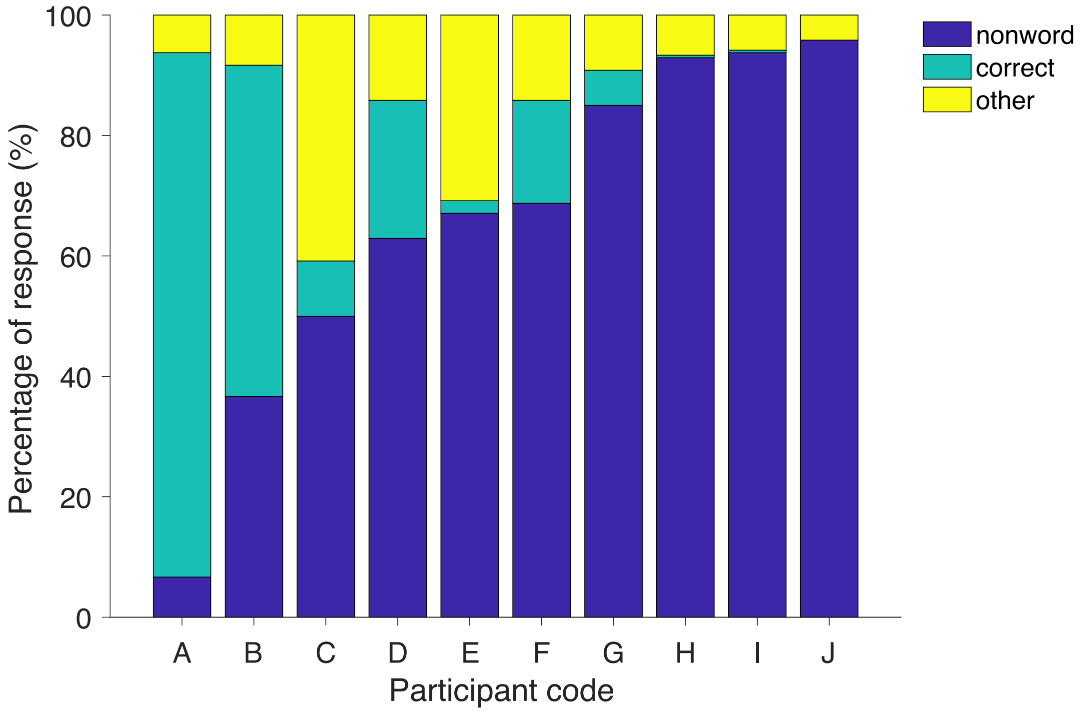


Figure 4.2: Proportion of correct, nonword and other error responses produced on single word production tasks

Table 4.1: Participant demographic and neurological information.

Participant Code	Age (years)	Gender	Time post stroke (months)	Aetiology	Lesion	Imaging
A	90	M	27	Haemorrhagic	pMTG, mMTG, pITG, TPJ	MR
B	71	M	78	unknown	pSTG, mMTG, pMTG, TPJ, IPL	MR
C	56	F	37	Poor-grade aneurysmal subarachnoid haemorrhage	ATL, pSTG, aSTG, TPJ	CT
D	62	M	11	Complete left carotid occlusion	-	Unavailable
E	71	M	57	Ischemic, secondary to surgery	aSTG, pSTG, mMTG, pMTG, pITG, TPJ, IPL	MR
F	74	F	9	Ischemic	ATL, mMTG, mITG, TPJ, IPL, MFG	CT
G	78	M	24	Haemorrhagic	pSTG, mMTG, mITG, TPJ, IPL, occ	MR
H	61	M	42	Ischemic and haemorrhagic	aSTG, pSTG, TPJ	MR
I	85	M	33	Ischemic	pSTG, pMTG, TPJ, IPL	MR - clinical
J	84	F	58	unknown	-	Unavailable

p = posterior; m = mid; a = anterior; STG = superior temporal gyrus; MTG = middle temporal gyrus; ITG = inferior temporal gyrus; TPJ = temporoparietal junction; IPL = inferior parietal lobule; MFG = middle frontal gyrus.

4.3.2 Neuroimaging

Lesion profiles are presented for the eight participants for whom neuroimaging data were available (see Figure 4.3). Imaging data were unavailable for participants D and J and they were unable to attend for scanning. T1-weighted MR research images were available for five individuals (A, B, E, G, and H), acquired on a Siemens Magnetom Trio 3T MRI scanner. Clinical CT scans were available for two participants (C and F) and a clinical MR was available for participant I. Lesion masks were drawn manually using MRIcron software (Rorden & Brett, 2000) and normalised using SPM8 (https://www.fil.ion.ucl.ac.uk/spm). The normalised masks were overlaid using MRIcron. Complete overlap (n = 8) was observed in a small number of voxels located at the junction of left superior temporal and inferior parietal lobe. High overlap (n = 7) was evident in a larger area including the left posterior middle temporal gyrus and superior temporal gyrus, conforming with lesion profiles typically reported in Jargon aphasia (Kertesz, 1981; Hillis, et al., 1999). Information about individual stroke onset, aetiology and lesion profile is provided in Table 4.1.

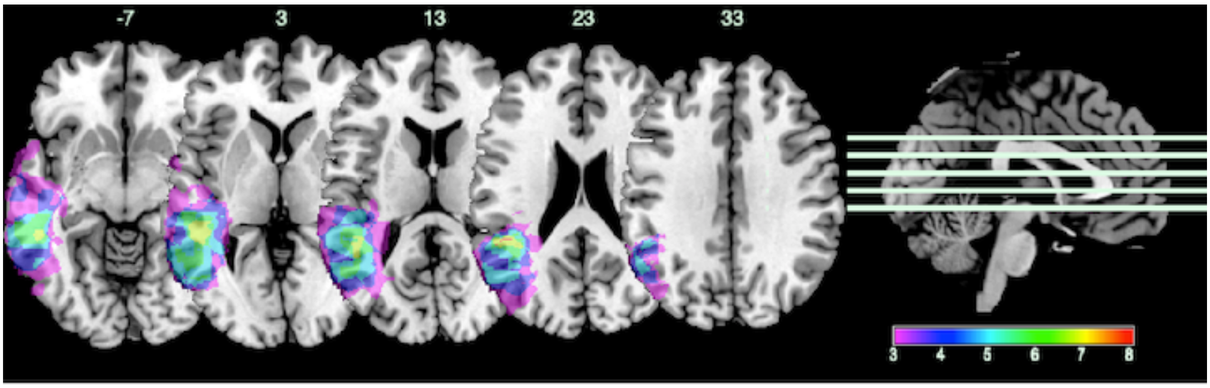


Figure 4.3: Lesion overlay identifying common regions of damage. MNI Z co-ordinate presented above each image. Colour bar indicates number of participants with lesion at each voxel (3 ≥ n ≥ 8).

4.3.3 Background testing

All participants were tested on semantic knowledge using both pictorial (Camel and Cactus, (CCT; Adlam, Patterson, Bozeat, & Hodges, 2010) and written (96 synonym judgement; Jefferies, Patterson, Jones, & Lambon Ralph, 2009) stimuli. Initial phoneme segmentation and written rhyme judgement tasks were administered (Psycholinguistic Assessment of Language Processing in Aphasia, PALPA; Kay, Lesser, & Coltheart, 1996) to assess phonological processing ability. To test basic visual processing, the shape detection screen and the position discrimination test from the Visual Object and Space Perception battery (VOSP, Warrington & James, 1991) were used. The shape discrimination screen is designed to identify presence of visual processing impairment such that no further testing should be done, and the participant be referred for specialist review; all participants in the current study passed this screen (see Table 4.2). The position discrimination test provides information on the patient's ability to perceive relative positions of objects in space. An in-house letter matching test was developed and used to assess whether participants were able to visually identify matching letter shapes. Participants were asked to match a probe grapheme, bigram or trigram to a target presented within an array of three distracters, presented in different fonts. As a marker of executive functioning, the trail making task from the Oxford Cognitive Screen (Demeyere, Riddoch, Slavkova, Bickerton, & Humphreys, 2015) was administered. The first two trail tasks required participants to link triangles and circles, respectively, in descending size order. For the third trial, participants were required to switch between circles and triangles, adhering to the descending size rule applied to the first two trail tests. Scores are reported separately for the non-switching and switching tasks according to successful connections made and a final executive score is calculated and used to identify presence of executive impairment.

Severe impairment in phonological processing skills (measured by phoneme segmentation) was observed at the group level and for all participants across the case-series. Additional, although less severe, impairment in semantic processing was observed at the group level and the case-series pattern revealed greater variation in the degree of semantic impairment across participants, with A, B, F, and I demonstrating more persevered semantic processing in comparison to participants C, D, G and H. The majority of the group presented with intact visual perception and processing ability indicated by high scores on the VOSP and letter matching tests apart from participants C and G who were identified as having impairments in visual perception by the position discrimination subtest (VOSP 2; see Table 4.2). Both participants C and G were also identified as having impaired executive functioning by the trail making tasks. They scored full marks on the single trail task (joining circles/triangles in descending size order) suggesting their visual deficit did not impact their ability to detect shape sizes and positions and that their impaired executive score validly indexes impaired executive control (see Table 4.2). Both participants C and G demonstrated impairment in grapheme matching suggesting impaired ability to detect letter shapes. This was mild for participant C (82% accuracy) and severe for participant G (45%). Participant J also presents with executive functioning impairment (see Table 4.2).

Table 4.2: Participant raw and percentage ( ) scores on semantic, phonological, visual processing assessments and executive assessments.

Participant Code	Camel & Cactus *n = 64*	96 synonym *n = 96*	Initial phoneme segmentation *n = 45*	Rhyme detection *n = 60*	Letter matching *n = 22*	VOSP(1) *n = 20*	VOSP(2) *n = 20*	Trail making 1 *n = 12*	Trail making 2 *n = 13*	Executive Score
A	42(66)*	80(83)*	35(78)*	53(88)	20(91)	19(95)	20(100)	12(100)	12(92)	0
B	59(92)*	91(95)*	22(49)*	47(78)	22(100)	20(100)	20(100)	12(100)	13(100)	-1
C	28(44)*	41(43)*	11(24)*	32(53)	18(82)	18(90)	17(85)*	12(100)	8(62)	4*
D	36(56)*	39(41)*	15(33)*	32(53)	22(100)	20(100)	20(100)	12(100)	10(77)	2
E	49(77)*	50(52)*	10(22)*	34(57)	22(100)	20(100)	20(100)	12(100)	13(100)	-1
F	51(80)*	84(88)*	23(51)*	32(53)	22(100)	20(100)	19(95)	12(100)	13(100)	-1
G	36(56)*	33(34)*	9(20)*	29(48)	10(45)	19(95)	16(80)*	12(100)	7(54)	5*
H	39(61)*	35(36)*	19(42)*	28(47)	21(95)	19(95)	19(95)	11(92)	13(100)	-2
I	48(75)*	91(95)*	9(20)*	46(77)	20(91)	18(90)	20(100)	12(100)	13(100)	-1
J	41(64)*	62(65)*	12(27)*	30(50)	21(95)	20(100)	20(100)	10(83)*	6(46)	4*
Mean	42.9(67)	60.6(63)	16.5(36)	36.3(60)	19.8(90)	19.3(96.5)	19.75(96)	11.7(97.5)	10.8(83)	
Cut off	53(83)	92(96)	39(86)	-	-	15(75)	18(90)	10(83) ●	4(31)	4

*Note: Participants presented in order of nonword production prevalence; n = x refers to total item number per assessment; 96 synonym: 96 written synonym judgement; VOSP(1): Visual Object and Space Perception battery screening test; VOSP(2): Visual Object and Space Perception battery position discrimination; ● trail making 1 comprises two separate tests with cut offs of 5 and 5.85, a combined threshold of 10 is adopted, * denotes impaired performance.*

4.3.4 Stimuli generation

Two hundred and forty words were selected from the MRC psycholinguistic database (Coltheart, 1981) (see Appendix 1 for word sets). These 240 words were organised into four separate sets of 60 items according to psycholinguistic properties related to lexical processing demands, as obtained from the MRC database (see Appendix 2). Independent one-way ANOVAs were used to statistically confirm that the lexical psycholinguistic properties varied across the four sets and that variables relating to phonological and graphemic processing were held constant. Two of the four sets had significantly lower values for frequency (KF, Celex/logged), concreteness, imageability and familiarity (MRC database statistics). Tukey post hoc tests were used and $p \leq .001$ was applied to post-hoc comparisons. All four word sets were matched for the phonological components; phonemic length, syllable length and number of letters ($p \geq .893$). The English Lexicon Project (ELP; Balota et al., 2007) database was used to extract orthographic and phonological neighbourhood density statistics for the four word sets. There was no difference observed across the four separate sets ($p \geq .230$). The phonotactic probability calculator (Vitevitch & Luce, 2004) was used to obtain values for position specific frequency of phonemes and biphones. There were no differences in phonotactic probability calculations across the four word sets ($p \geq .765$). The ELP data for bigram position specific frequency also indicated no difference across the four word sets ($p = .320$). Appendix 7 sets out the mean and standard deviation data for psycholinguistic variation across the four-word sets. From herein, the two word sets with higher frequency, imageability, concreteness and familiarity values will be labelled *'high'* to reflect their lexical availability, whilst the remaining two sets will be labelled *'low'*, in accordance with their lower availability. One high and one low set were used for word repetition and the remaining high and low sets were used for word reading.

4.3.5 Procedure

Data were collected by the first author and all participants were visited in their own homes. For word repetition, the target words were pre-recorded, to control for variability in production across time points and participants. The single word recordings were then presented for repetition during data collection. A fixation cross was present at the centre of the screen throughout the repetition testing. For word reading single written words were presented in the centre of a laptop computer screen. In between the words, a fixation cross was presented for 1000ms. Participants were instructed to repeat/read the target word aloud to the best of their ability. No explicit time pressure was applied. The experimenter moved participants onto the next target word following three unsuccessful attempts at production. Participants read/repeated all 60 words from a single set consecutively, without breaks. Task and difficulty conditions were administered in a counterbalanced order across participants. Audio recordings were taken throughout testing and participants' responses were transcribed in broad phonemic transcription in real time and subsequently checked against the recording before electronic data entry. Electronic transcriptions were coded in DISC symbols which have 1:1 phoneme-symbol correspondence (e.g. /u:/ = u) to enable automated data analysis, using Microsoft Excel and MATLAB. Participant B produced semantic errors in word repetition and so these data are omitted from the current analysis. Participant C was unable to produce any verbal response to written words. The background testing scores indicate that she presents with mild impairment on both the position discrimination task and the letter matching task (see Figure 2) and moderate written word comprehension (see Figure 1). It is beyond the scope of the current study to further test and diagnose the nature of her dyslexia. Due to her inability to produce any verbal response to written stimuli and the subsequent emotional stress placed on her as a result of this task, reading aloud was not completed with this individual.

4.3.6 Recording and error analysis

Responses were coded based on criteria presented in Dell et al., (1997) with lexical (real word) responses categorised as correct or not and incorrect lexical responses categorised as ‘other’ error types. Other error types consisted of formal errors, denoting when a real word response was phonologically related to the target in either initial phoneme or there was 50% phonological overlap between the target and the response; unrelated errors, when a real word error had no semantic or phonological relationship to the target; semantic when the response was related in meaning to the target word; mixed, indicating that the response has both a semantic and phonological relationship to the target; and a non-response, when the participant produced no verbal response or indicated that they did not know. Non-lexical errors (a string of phonemes that do not constitute a word in the English language) were identified and labelled as nonwords.

Error numbers were inspected to confirm that nonword errors were most common, indicating the presence of Jargon aphasia (see Figure 2, Appendix 3). Subsequent analyses focused solely on nonwords because of their dominance and relevance in Jargon aphasia. To explore whether nonword Jargon production is influenced by lexical availability, a repeated measures factorial ANOVA was used to identify whether the number of nonwords differed under the lexical availability (high and low) or task (repetition and reading) conditions at the group level. Participants B and C are excluded from this repeated measures analysis due to incomplete data sets. Case-series analyses were then conducted using individual Fisher's tests were used to determine whether there was an effect of lexical availability on the number of nonwords produced by each participant on the separate production tasks.

4.3.7 Phonological accuracy analysis

The Phonological Overlap Index measure (POI; Schwartz et al., 2004) was used to quantify how many phonemes a nonword contained in relation to its target word form. The POI formula,

Number of phonemes shared between response and target x2)/
(total phonemes in target + total phonemes in response)

assigns nonwords a value between zero and one. By this calculation, nonwords containing no target phonology obtain a value of zero (e.g. "earth", /bændrɪəl/) and nonwords containing higher proportions of target phonology obtaining scores closer to one (e.g. "mortal", /mɔːltə/). Whilst both errors would be categorised as nonwords in the first analysis, the POI metric provides more detail about the degree of phonological disruption within errors, meaning production can be quantified with greater sensitivity. The POI was calculated for all nonword responses produced by each participant to determine whether higher availability words exerted greater constraint and generated more accurate phonological production, in comparison to words with lower lexical availability when phonological constraints were controlled for. A repeated measures factorial ANOVA was used to determine whether there was an effect of lexical availability (high and low) or task (repetition and reading) at the group level and independent non-parametric t tests were used to explore the effect of lexical availability (high and low) on nonword POI for each participant across repetition and reading separately.

4.3.8 Perseveration analysis

The current measure of perseveration is presented in an unpublished thesis (Godbold, 2017) and is adapted from methods presented in McCloskey, Macaruso, and Rapp (2006). For this analysis, all intruded (erroneous) phonemes within a given nonword response are identified and then searched for within the previous production. The number of intruded phonemes found within the immediate production is summed and divided by the total number of intrusions, quantifying how many phoneme errors are perseverations. For example, participant J repeated the target word 'wedding' as /gɒreɪd/, intruding the four phonemes /g/, /ɒ/, /r/ and /eɪ/. The preceding response /gɒred/ contained three of these error phonemes (/g/, /ɒ/ and /r/), generating an intrusion-perseveration score of 0.75. By this calculation, each nonword response is assigned an intrusion-perseveration score, which falls between zero (indicating errors were not present in the immediately preceding response) and one (indicating all errors were produced on the immediately preceding production). Where multiple occurrences of phonemes are produced within a single response, only 1:1 intrusion – previous production matches are counted. This method identifies phoneme perseverations produced within the previous production only. Phoneme perseverations are most commonly observed across responses in close proximity to a source production, at a lag of one, two or three responses, with errors produced later in time (at a lag of 4 onwards) bearing only chance perseverative relationships (Cohen & Dehaene, 1998). The current measure focused on a response lag of one as phoneme perseverations are most significant and consistent at this temporal resolution (Ackerman & Ellis, 2007; Corbett et al., 2008; Martin & Dell, 2007) and therefore would sufficiently index Jargon production for the current hypothesis testing.

A repeated measures factorial ANOVA was used to determine whether there was an effect of lexical availability (high and low) or task (repetition and reading) on the intrusion-perseveration score at the group level for the 7 participants of the eight participants with complete data sets. Participant A was not included in the perseveration analyses as he produced insufficient errors in the reading tasks to allow a perseveration analysis to be carried out (he made one error in the highly available reading task and three errors in the low availability condition; see Appendix 3). Independent non-parametric t tests were used to explore the effect of lexical availability (high and low) on perseveration for each participant, across reading and repetition separately.

4.3.9 Summarising the lexicality effect

For each individual, the statistics identified by the three separate production measures (nonword number, phonological accuracy and intrusion-perseveration score) were used to deduce a difference score. This was done in the direction of the hypothesis, e.g. nonword number for the low availability word set minus nonword number for the high availability word set. The group mean and standard deviation of the difference scores was calculated for each of the three production measures, for repetition and reading separately. The mean was then deducted from each individual difference statistic and divided by the standard deviation to deduce a Z score for each difference statistic. By this approach, a greater Z score represents a higher difference statistic in the direction of the hypothesis, e.g. nonword number in the low availability word set was greater than nonword number observed in the high availability word set, in relation to the difference statistics across the rest of the group. This approach was adopted to support identification of individuals who exhibited most behavioural difference in response to the lexical availability manipulation. The difference statistics were entered into separate repeated measured non-parametric t tests to determine whether the difference scores were different between repetition and reading. Data from the eight participants with complete datasets were entered into this analysis.

4.4 *Results*

4.4.1 Nonword prevalence

All ten participants produced nonwords as the dominant error type (see *Figure 4.2*). Participant A produced the fewest nonword errors with approximately seven percent of his responses labelled as nonwords and participant J presented with the most severe Jargon output, with responses comprising 96% nonwords (see *Figure 4.2*, Appendix 3). Four participants (C, D, E and F) produced notable numbers of 'other' errors (see Appendix 3). For participant C, other errors were either real word errors that were unrelated to the target (13%), real word errors that were phonologically related to the target (8%), or non-responses (19%). Participant D produced real word errors that were either phonologically related (9%) or unrelated to the target (5%). For participant E, the majority of other errors were either real words with no phonological or semantic relationship to the target word (16%) or real word errors that were phonologically related to the target (15%). Data inspection indicated that unrelated real-word error productions appeared to arise from whole word perseverations and/or idiosyncratic productions. Participant F's other error productions were either phonologically related (8%) or unrelated (4%) real word responses. The remaining six participants (A, B, G, H, I and J) produced other error responses less than 10% of the time (see *Figure 4.2*). On inspection, all nonword errors conformed to English phonotactics.

A repeated measures factorial ANOVA was used to determine whether lexical availability (high or low) or production task (reading and repetition) influenced the number of nonwords produced. Results indicated that there was a main effect of lexical availability ($F(1,7) = 7.627$, $p = .028$, $\eta p^2 = .521$) demonstrating that more nonwords were produced when targets were less available (high $\bar{x} = 39.4$, low $\bar{x} = 46.5$). There was no main effect of production task ($F(1,7) = 1.292$, $p = .293$, $\eta p^2 = .156$, see Figure 4.4) and no interaction between task and lexical availability ($F(1,7) = 2.517$, $p = .157$, $\eta p^2 = .264$). As participant B and C have incomplete data sets, they are discounted from the group level repeated measures analysis.

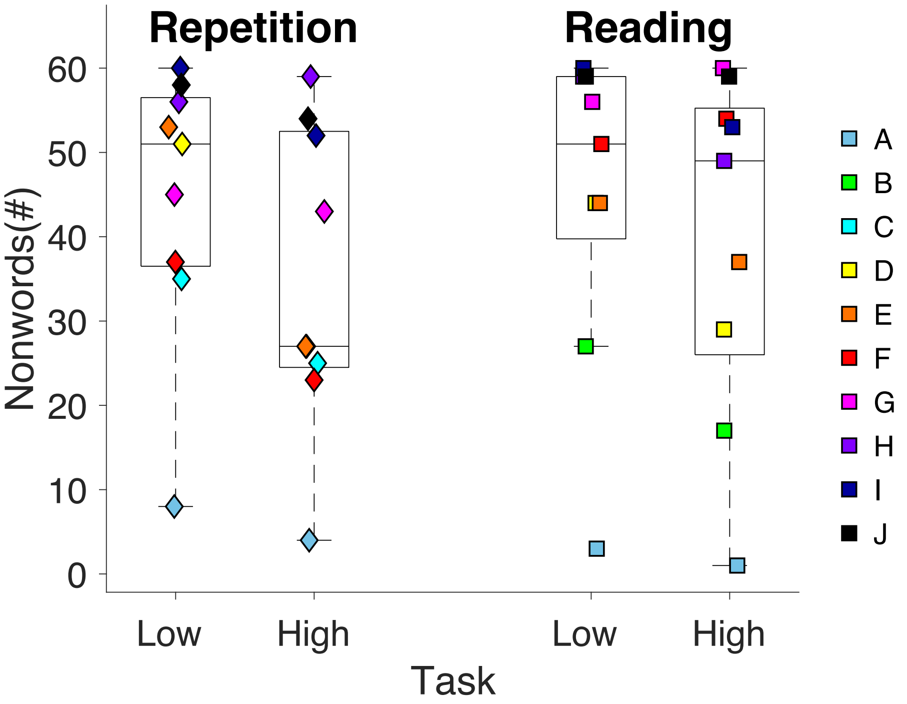


Figure 4.4: Number of nonwords produced on low and high availability word sets for repetition and reading. Individual markers indicate total nonwords produced by each participant. Participant colours presented in key.

At the individual level, eight of the nine participants produced more nonwords in the low availability repetition task. Fisher's exact test identified that this was statistically significant in participants D, E, F and I ($p \leq .006$, see Table 3). Participant H produced marginally more nonwords in the highly available condition; however, this was not statistically significant ($p = 0.364$). In word reading, seven participants produced more nonwords when the target lexical item was less available. This was statistically significant in participants D, H and I ($p \leq .013$, see Table 3). Participants F and G produced more nonwords on the highly available word reading set; however, these effects did not reach statistical significance ($p \geq .119$).

Table 4.3: Number of nonwords and Fishers p test statistics for lexicality effect on number of nonwords in repetition and reading.

	Repetition			Reading		
Participant	Low	High	Fishers *p*	Low	High	Fishers *p*
A	8	4	.362	3	1	.619
B	-	-	-	27	17	.088
C	35	25	.100	-	-	-
D	51	27	≤ .001	44	29	.009
E	53	27	≤ .001	44	37	.242
F	37	23	.006	51	54	.582
G	45	43	.837	56	60	.119
H	56	59	.364	59	49	.004
I	60	52	.006	60	53	.013
J	58	54	.272	59	59	1.000

4.4.2 Phonological accuracy

A repeated measures ANOVA was used to determine whether there was an effect of lexical availability (high or low) or task (repetition and reading) on phonological production accuracy (POI) of nonwords at the group level. The POI measure quantifies nonword accuracy on a scale ranging from 0 to 1, where 0 indicates no phonological overlap and 1 indicates all target phonemes were produced. The ANOVA demonstrated that there was no significant effect of lexical availability ($F(1,7) = 1.308$, $p = .290$, $\eta p^2 = .157$), production task ($F(1,7) = 2.190$, $p = .182$, $\eta p^2 = .238$), or interaction effect ($F(1,7) = .321$, $p = .589$, $\eta p^2 = .044$; see Figure 4.5).

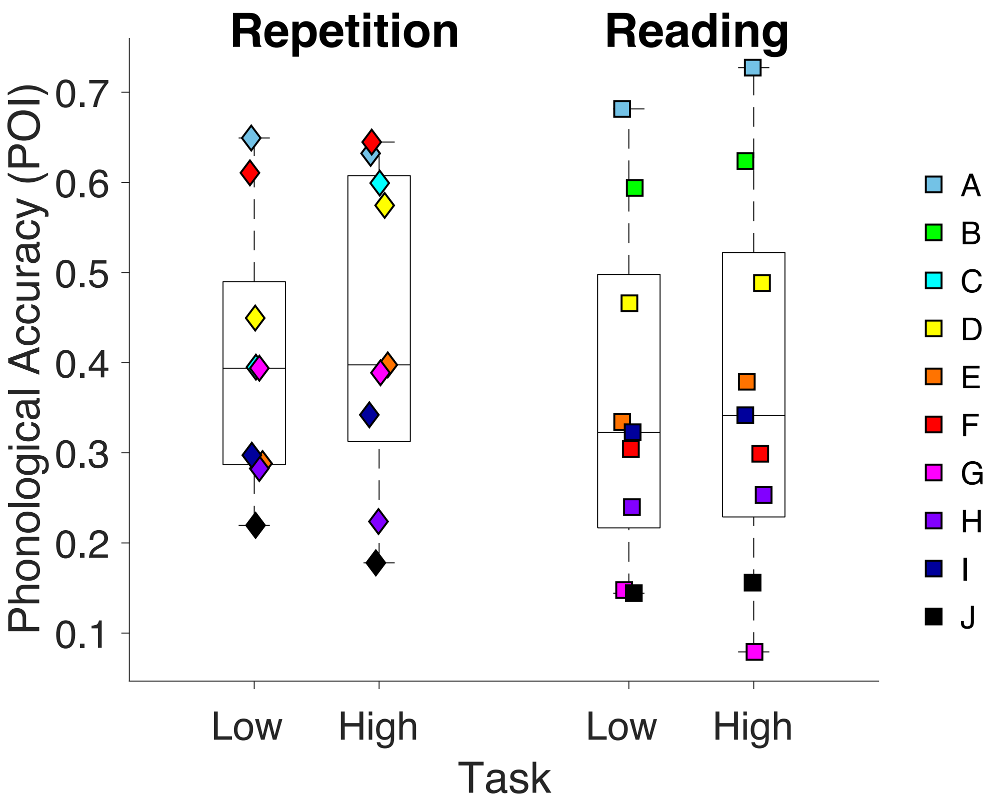


Figure 4.5: Mean Phonological Overlap Index (POI) for low and high availability word sets for repetition and reading. Individual markers indicate participant means. Participant colours presented in key.

At the individual level, nonparametric t tests identified that participants C and D were more phonologically accurate when repeating the easier, highly available word set ($p \leq .017$, see Table 4.4, Figure 4.6). The remaining seven participants demonstrated no effect of lexical availability on the phonological accuracy of nonwords ($p \geq .059$, see Table 4.4 Figure 4.6). In word reading, participant G produced more target phonology when lexical items were less accessible ($p = .016$; see Figure 6). The remaining eight participants demonstrated no effect of lexical availability on their nonword accuracy in word reading ($p \geq .256$, see Figure 4.6).

Table 4.4: Mann Whitney U test statistics for lexicality effect on POI in repetition and reading per participant.

	Repetition		***Reading***	
Participant	*U*	*P*	*U*	*p*
A	15	.798	-	-
B	-	-	206	.570
C	212	.001	-	-
D	462	.017	592	.599
E	531	.059	695	.256
F	363	.336	1361	.915
G	953	.903	1288	.016
H	1346	.085	1399	.770
I	1369	.263	1375	.727
J	1362	.226	1698	.813

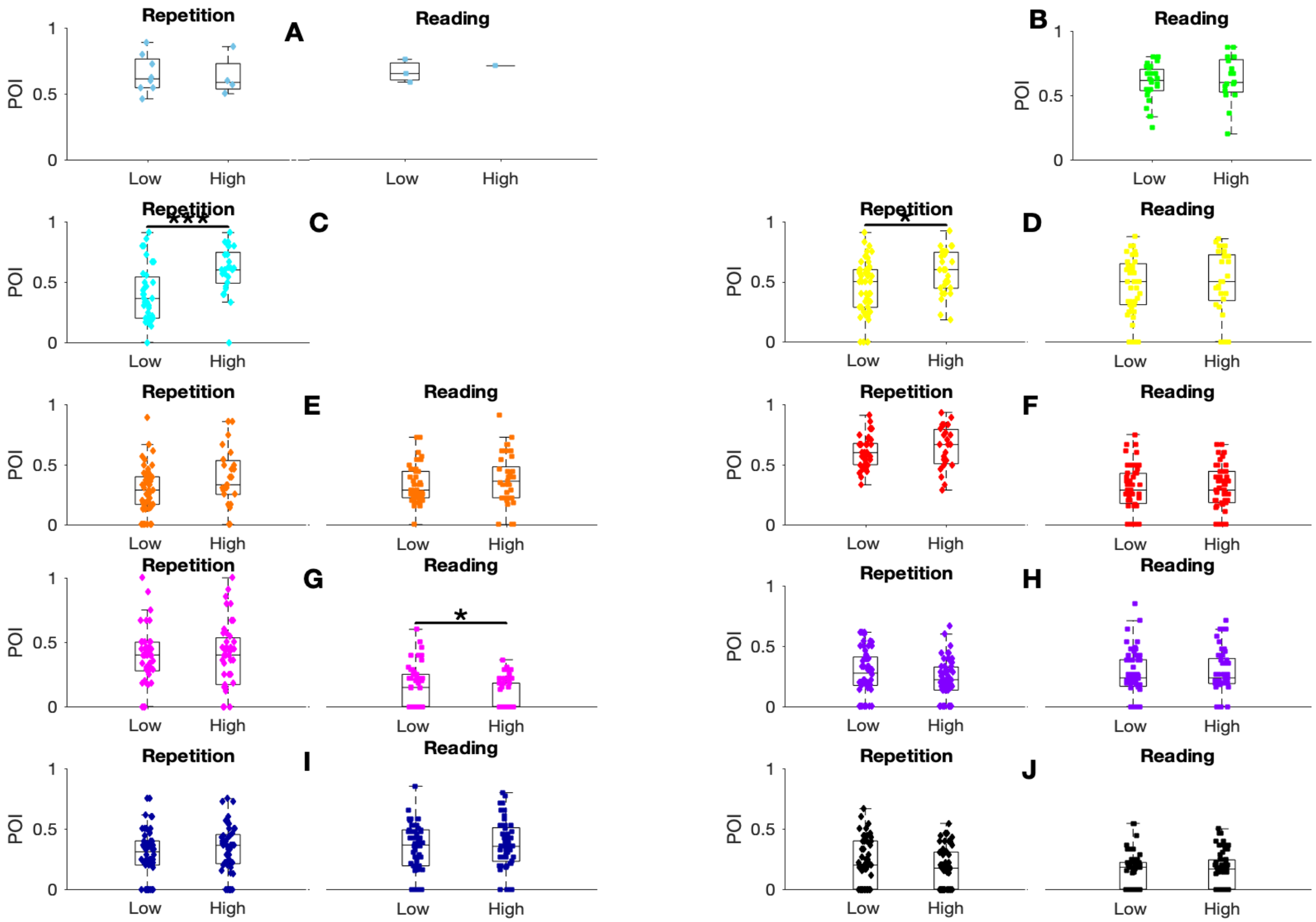


Figure 4.6: Phonological Overlap Index scores and distributions for nonword errors produced by each participant in the high and low availability conditions in repetition and reading. Stars indicate significance levels: p ≤ .05, p ≤ .01**, p ≤ .001****

4.4.3 Perseveration

The perseveration calculation assigned every nonword response an intrusion-perseveration score between zero and one, quantifying the likelihood that phoneme errors within nonwords were present in the immediately preceding production. For the group level analysis average perseveration scores for the seven individuals with complete data sets were entered into a repeated measures factorial ANOVA to examine whether lexical availability and production task influenced perseveration. Participant A is excluded from this analysis since he produces insufficient errors in word reading for this analysis (see Table 3). Results demonstrated no effect of lexical availability ($F(1,6) = 2.129$, $p = .296$, $\eta p2 = .179$), production task ($F(1,6) = 2.129$, $p = .195$, $\eta p2 = .262$) or interaction ($F(1,6) = 1.853$, $p = .222$, $\eta p2 = .236$), indicating perseveration rates were similar across the different tasks and conditions (see Figure 7).

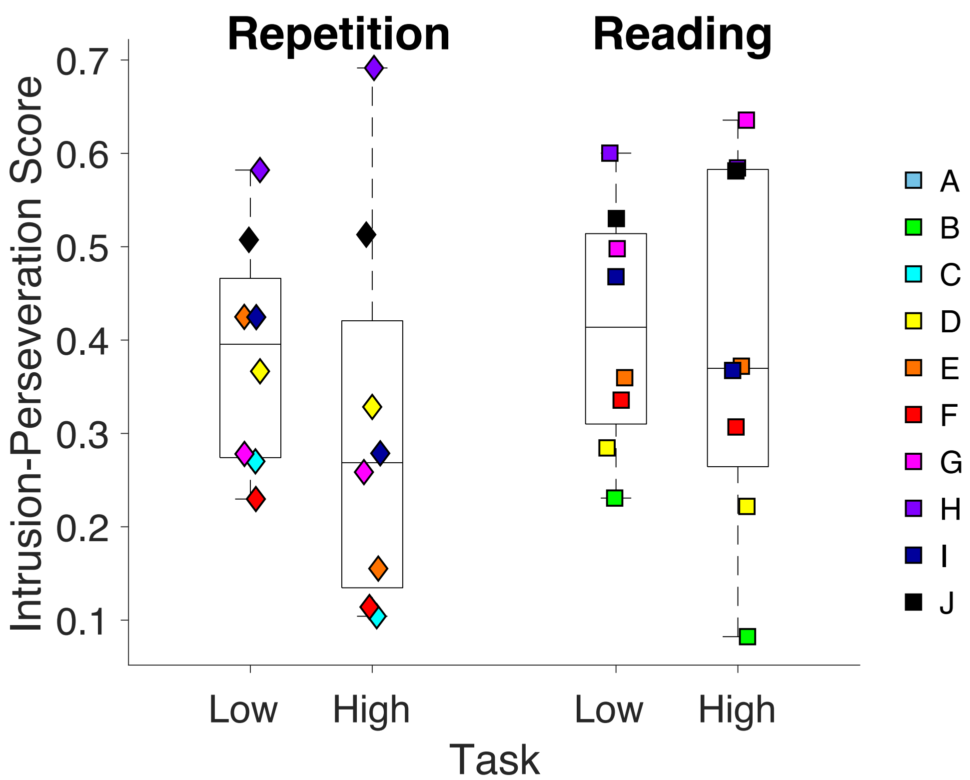


Figure 4.7: Mean intrusion perseveration score for low and high availability word sets for repetition and reading. Individual markers indicate participant means. Participant colours presented in key.

Individual non-parametric t tests identified that, in repetition, participants C, E and I were more perseverative when lexical availability was less ($p \leq .038$, see Table 5, Figure 7). Participants A, D, F, G and J exhibited no differences in their perseveration across the lexicality conditions in repetition ($p \geq .267$, see Table 5, Figure 8) and participant H produced more perseveration when lexical availability was higher ($p = .020$). In word reading, rates of perseveration were similar for all individuals ($p \geq .074$) apart from participant G who was more perseverative when lexical availability was higher ($p = .008$, see Table 4.5, Figure 4.8: Intrusion-perseveration scores and distributions for nonword errors produced by each participant in the high and low availability conditions in repetition and reading. Stars indicate significance levels: p ≤ .05*, p ≤ .01**, p ≤ .001***.).

Table 4.5: Mann Whitney U test statistics for lexicality effect on intrusion-perseveration score in repetition and reading for each participant.

	Repetition		***Reading***	
	U	*p*	U	*p*
A	12.0	.418	-	-
B	-	-	155.0	.122
C	294.0	.038	-	-
D	634.5	.400	553.0	.373
E	372.5	.001	743.0	.756
F	357.5	.267	1323.5	.992
G	875.5	.664	1158.0	.008
H	1242.0	.020	1370.5	.891
I	983.0	.002	1101.0	.074
J	1542.5	.902	1538.5	.426

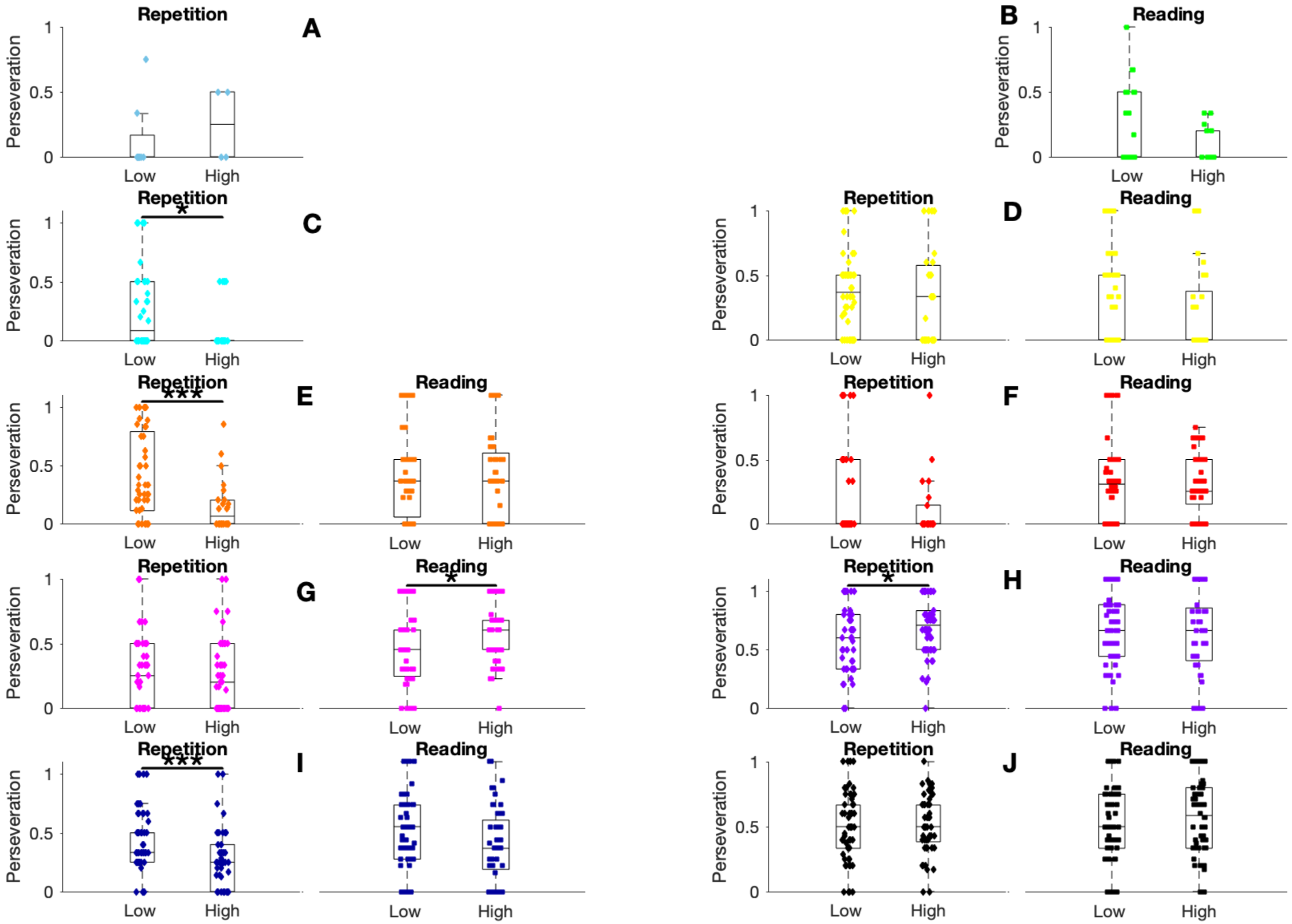


Figure 4.8: Intrusion-perseveration scores and distributions for nonword errors produced by each participant in the high and low availability conditions in repetition and reading. Stars indicate significance levels: p ≤ .05, p ≤ .01**, p ≤ .001***.*

4.4.4 Summarising the lexicality effect

The difference in participant performance between the low and high availability conditions was calculated for each of the three Jargon measures – number of nonwords, phonological accuracy of nonwords (POI) and phoneme perseveration within nonwords (intrusion-perseveration probability; IPS). These difference statistics, which were calculated for repetition and reading separately, were used to derive a *Z* score for each participant. By this approach, the *Z* score represents the degree of behavioural difference between the low and high lexical availability conditions relative to the rest of the group and is used to identify participants who exhibited the strongest effects of the lexicality manipulation. The plots represent the distribution of difference statistics across the group and demonstrate that participants with moderate Jargon impairments (C, D, and E) exhibited the greatest and most consistent effects of the lexical manipulation. The *Z* score distributions were more variable across the reading aloud measures, with lexicality effects for phonological accuracy clustering close to zero for everyone except participant G, who exhibits a significant reverse frequency effect (see Figure 4.9).

To identify whether production task influenced the degree of lexicality effects, the difference statistic for each production measure for each participant was entered into a Wilcoxon signed rank test. One statistical test was carried out for each of the production measures. Results demonstrated that lexicality effects were not significantly different across repetition and reading for number of nonwords (Z = -1.680, p = .093), phonological accuracy (Z = -.560, p = .575) or for the intrusion-perseveration score (Z = -1.352, p = .176).

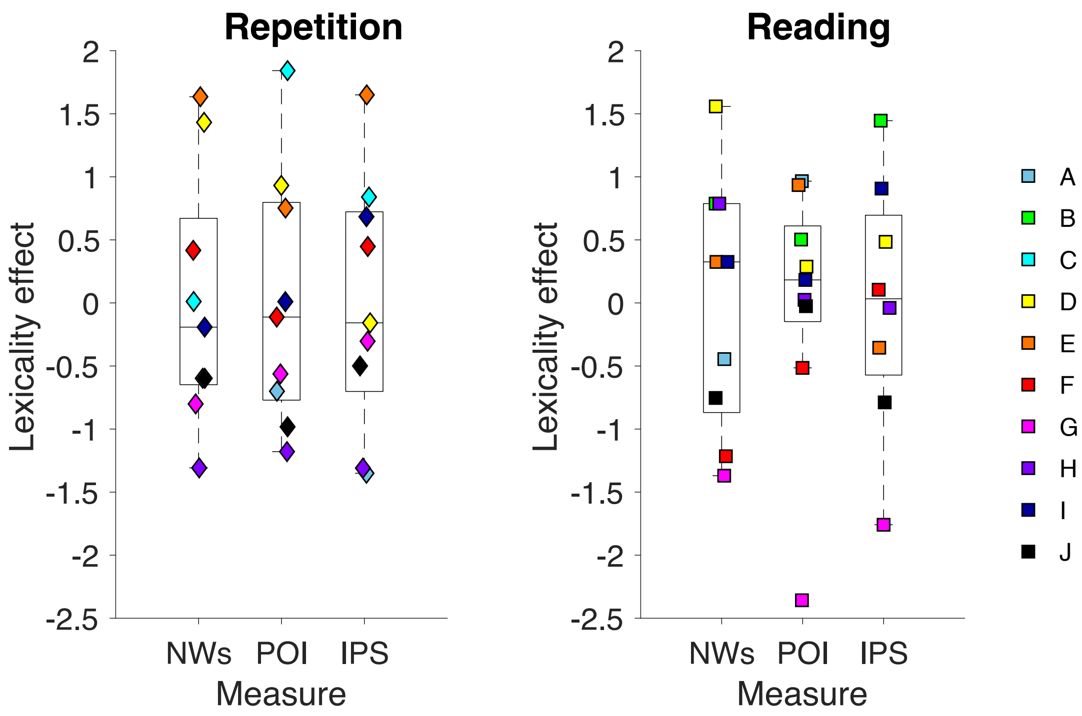


Figure 4.9: Lexical effect observed for each participant across the three different production measures in repetition and reading. NWs = nonwords, POI = Phonological Overlap Index, IPS =Intrusion Perseveration Score.

4.5 ***Discussion***

This study examined whether lexical availability impacted on phonological production in Jargon aphasia. To test this, word lists of either high availability lexical items (high frequency, familiarity, imageability and concreteness) or low availability lexical items (low frequency, familiarity, imageability and concreteness) were presented for production in tasks of single word repetition and reading aloud. Crucially, the phonological processing demands of these word lists were carefully matched to ensure that lexical availability was the psycholinguistic variable under scrutiny. Jargon production was measured for quantity (number of nonwords) and quality (phonological accuracy and phoneme perseveration within nonwords). Results demonstrated that lexical availability impacts the amount of Jargon produced in that, at the group level, significantly more nonwords were produced when target words had lower lexical availability. When analysing the phonological accuracy and phoneme perseveration within nonwords, no effects of lexical availability were observed. These group level results suggest that lexical availability has a somewhat binary effect on Jargon nonword production. When lexical availability was greater, significantly fewer nonwords were observed, suggesting more successful constraint from lexical processing in minimising nonword production. However, when analysing the quality of nonword errors, lexical availability failed to influence the phonological accuracy and perseveration. This indicates that the phonological processing underpinning nonword production does not benefit from more readily available lexical information and implies that alternative processing routes, i.e. nonlexical avenues are more influential in nonword production, during reading and repetition.

The case series analyses revealed a more nuanced pattern, with a subset of participants producing fewer nonwords (participants D, E, F and I), greater phonological accuracy within nonwords (participants C and D) and less phoneme perseveration (participants C, E and I) when repeating the highly available words. These results suggest that phonological processing in a portion of individuals with Jargon aphasia is influenced by lexical factors. Since the lesion and neuropsychological profile associated with Jargon aphasia indicates severe and consistent phonological processing impairment alongside variable impairment in lexical-semantic processing (Robson et al., 2017), it is reasonable to expect that individuals with greater capacity to process lexical-semantic information would demonstrate greater effects of lexicality, adhering to trends exhibited by neurologically healthy controls and patient groups with preserved lexical-semantic processing (Jefferies et al., 2006; Martin & Saffran, 1997). In the current study all participants displayed a degree of semantic impairment (see Table 2); however, no relationship was observed between the degree of semantic impairment and lexical effect size, and the subset of participants who exhibited lexical effects (C, D, E) mostly displayed poor lexical-semantic abilities. In addition, there was no relationship between the number of nonwords produced (Jargon severity) and nonverbal-semantic abilities (Camel & Cactus Test, r = 0.12, p = .737) or lexical-semantic abilities (96 synonym judgement, r = 0.313, p = .377), indicating a lower, non-systematic influence of lexical-semantic processing on Jargon production. Instead, Jargon severity was linearly related to phonological processing abilities (phoneme discrimination, r = -0.73, p = .016; rhyme judgement r = -0.66, p = .037) consistent with the hypothesis that phonological processes underpin Jargon production. Analysis of the phonological accuracy and perseveration measures of production quality further support this finding, as significant linear relationships were observed between the POI metric and phonological abilities (Rhyme judgement, $r = .672$, $p = 0.33$ and Phoneme discrimination $r = -.693$, $p = .026$). No statistical relationship was observed between production quality metrics and semantic abilities (POI: $.218 < r < .426$, $p > .219$; Intrusion-Perseveration Score: ($-.215 > r > -.446$, $p > .196$). It appears that the individuals who displayed lexical influences on phonological production were those with moderate degrees of Jargon severity and phonological processing ability. It is interpreted that lexical effects do not emerge in participants with mild (participants A and B) or severe (participants F, G, H and J) Jargon because the extent of the phonological impairment masks the lexical effects. By this interpretation, when phonological processing is better preserved, resulting in mild Jargon aphasia, there is sufficiently specified (although not entirely accurate) phonological activity and the magnitude of the lexical manipulation is insufficient to produce a measurable influence on phonological processing. At the opposing end, in severe Jargon where the phonological processing is significantly impaired, lexical processes are equally insufficient to overcome the impairments within the phonological system (Kohn et al., 1996). The degree of phonological impairment associated with moderate Jargon production, as observed in participants C, D, and E, is optimum for lexical effects to emerge. Having said this, participant I also demonstrates lexical effects, despite presenting with severe phonological processing impairment (see Table 2). The lexical effects exhibited by participant I may be explained by the strong dissociation between his lexical-semantic abilities (relatively preserved) and phonological abilities (severely impaired), suggesting that lexical information can impact severely impaired phonological processing if the former is particularly strong. Taken together, current results suggest that lexical effects may be generated by an interaction between lexical-semantic and phonological processes; with lexical effects depending on the severity of phonological and semantic impairments and implying that people with stronger semantic ability capitalise on this to facilitate phonological production. These results imply that people with moderate Jargon aphasia may be more able to communicate when conversation focuses on highly frequent and familiar topics, and further work focusing on this pattern in Jargon and phonological forms of aphasia is required to better understand the nature and clinical implications of this interaction.

Within participant effects added a further layer of complexity, as lexical effects differed by behavioural measure. For example, Participants I and E deviate from the group pattern in that their perseveration was impacted by lexical availability alongside the number of nonwords, but the phonological accuracy of nonwords (POI) was unaffected. In contrast, participant D displays the opposite pattern, whereby the nonword POI but not the degree of perseveration was affected by lexical availability. These patterns are unexpected in that perseverative and nonword errors are hypothesised to arise from the same mechanism; deficient target activation (Hirsh, 1998; Martin & Dell, 2007). By this account, perseveration happens when phonological segments from the target word are weakly activated, creating greater opportunity for units with residual activation to compete and intrude and, therefore, higher perseveration should coincide with lower POI scores. However, the dissociative results from the current study indicate that the mechanisms underpinning perseverative and nonword errors are more complex. One explanation of the perseveration-POI dissociation is that the nature of the phonological impairment may differ between individuals. Kohn et al. (1996) suggest that phonological impairments in Jargon aphasia can be due to lost phonological representations or reduced access to phonological representations. Where Jargon production is underpinned by impaired access to existing representations phonological encoding can comprise segments from multiple non-target representations which are neighbouring or associated with the target. Those with lost phonological representations have less or no opportunity to make use of neighbouring representations resulting in greater reliance on previously used phonology and increased perseveration. Increasing the amount of activity in the phonological system, e.g. in the high lexical availability condition, could either support phonological representation access resulting in increased POI, or could bias activation away from previously active phonology resulting in lower perseveration, thus accounting for why lexical effects were observed in only one outcome measure. However, the access vs. loss hypothesis cannot account for the full pattern of data uncovered by the current study, in particular that reverse lexical availability effects were also observed.

Participants G and H displayed greater perseveration in the high lexical availability condition in reading and repetition, respectively. One possible explanation is that impaired inhibition is a further factor in the perseveration impairment displayed by these participants (Fischer-Baum & Rapp, 2012) and that this mechanism interacts with greater activity in the high lexical availability condition. Spreading activation accounts suggest that higher frequency words produce richer activity patterns than lower frequency words due to their diverse usage (Bose, van Lieshout, & Squares, 2007; Dell et al., 1997; Hoffman, Jefferies & Lambon Ralph, 2011; Marshall, Pring, Chiat & Robson, 2001), which may be associated with greater inhibitory demands. Marshall, Pring, Chiat and Robson (2001) use this account to explain the reverse frequency effect observed in their participant JP, who produced low frequency words more accurately than high frequency words. The authors suggest that high frequency words are associated with multiple semantic neighbours, which, by the spreading activation account, may result in excessive activation spreading and more extensive phonological activation. Low frequency words are associated with fewer semantic neighbours and therefore generate a more refined pattern of phonological activation. By this account, higher frequency items would elicit greater phonological activation and increase inhibitory demands, eliciting greater perseveration for people with inhibitory deficits.

A secondary hypothesis in the current study was that lexical effects would be enhanced in reading aloud in comparison to auditory repetition. This hypothesis was motivated by the lesion profile associated with Jargon aphasia which commonly involves the left supramarginal gyrus and superior temporal gyrus which are associated with auditory-phonological processing (Buchsbaum et al., 2011; Buchsbaum, Hickok & Humphries, 2001). In repetition, lexical information is accessed via auditory input phonology, whereas word reading is initiated by visual processing. In Jargon aphasia, posterior regions associated with visual processing typically remain intact and functional, meaning access to lexical information can proceed more accurately (Robson et al., 2012). This pattern explains why comprehension of written material is privileged over comprehension of spoken material (see Table 1). Furthermore, a study by Nozari and Dell (2013) indicated that people with aphasia have preferences for lexical or nonlexical processing dependent on their lexical-semantic comprehension abilities; greater lexical access and comprehension ability is associated with greater weight on lexical processing, whereas more severely disrupted lexical processing capacity increases the likelihood that nonlexical processing will be utilised. Taken together, this suggests that lexical processing should be enhanced in word reading and therefore lexical effects should be exaggerated in this task. However, the case study patterns in the current group revealed the opposite effect; lexical effects were observed more so in word repetition (see Figures 3, 5 and 6). This unexpected effect can be attributed to the different transience of written and spoken stimuli in the reading and repetition tasks. Repetition involves presentation of auditory material that is highly transient, whereas reading involves the presentation of static written material which, in the current study, was present on the screen until the participant had completed their response. This inherent difference in stimuli is likely to encourage differential processing in the different tasks, with reading encouraging focus on nonlexical material since letters remain available throughout production processing, whereas repetition minimises this approach to processing since phonological material is highly transient. Therefore, repetition appears to increase use of lexical route processing as it revealed more effects of the lexical availability manipulation in the current study.

In addition to the greater lexical effects, repetition also demonstrated greater accuracy compared to reading, in participants C, F and G (see Figures 5 and 7). Participants C and G displayed a visual processing impairment as measured by the VOSP (Table 2) and participants F and G displayed lesion involvement of middle to posterior inferior temporal regions, therefore indicating direct damage to visual components of the reading network in these participants (Cohen & Dehaene, 2004; Cohen, Dehaene, Vinckier, Jobert, Montavont, 2008; Richardson, Seghier, Leff, Thomas, & Price, 2011). However, participants A and E also displayed inferior posterior temporal lobe involvement without a disproportionate reading impairment, emphasising the need for in-depth explorations of structural and functional alterations to help explain the dissociative patterns found in this and other studies of Jargon aphasia (e.g. Moses et al., 2004; Olson et al., 2015).

Conclusion

This study found that lexical information does not consistently influence phonological production in a group of people with Jargon aphasia. Instead, phonological accuracy in single word production is only consistently influenced by lexical information when phonological processing ability is moderately impaired. For people with more severe Jargon impairments, maximal amounts of lexical information do not consistently enhance phonological production; however, lexical effects were observed in one participant who displayed preserved semantic abilities, suggesting that lexical effects were dependent upon both lexical-semantic and phonological processing impairments and that lexical processing is utilised in Jargon repetition. Reading aloud demonstrated little evidence of lexical variables, suggesting that people with Jargon do not utilise their lexical processing route to facilitate and support phonological encoding, instead displaying a maladaptive strategy of focusing on phonological material to achieve production.

Chapter 5. Manipulating Phonological Encoding Conditions in Jargon Aphasia: Impact on Production Severity.

Emma Pilkington[a*], Karen Sage[b], Douglas Saddy[a], and Holly Robson[a]

[a]*School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK.*
[b]*Department of Allied Health Professions, Sheffield Hallam University, Sheffield, UK.*

**School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK, RG6 7BE. E.c.pilkington@pgr.reading.ac.uk*

Chapter 5 information

This chapter is presented as a manuscript which is planned for submission to the *Journal of Cognitive Neuropsychology* following thesis completion. This study includes participants who were recruited by both Emma Pilkington and Holly Robson and all data was collected by Emma Pilkington as part of PhD completion at the University of Reading. Ethical approval for this study was obtained from the University of Reading School of Psychology and Clinical Language Sciences Ethics Board (see Appendices 8.2, 8.3, 8.4, 8.5).

Authorship statement

E. Pilkington: conceptualisation; methodology; resources (recruitment and data collection), curation and analysis; manuscript preparation; visualisation; funding acquisition.
K. Sage: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
D. Saddy: conceptualisation; methodology; manuscript review and editing; supervision; funding acquisition.
H. Robson: conceptualisation; methodology; resources (participant recruitment); manuscript review and editing; supervision; funding acquisition.

5.1 ***Introduction***

5.1.1 Jargon aphasia spoken production

Jargon aphasia is a severe form of acquired language impairment associated with phonological error in spoken production. Phonological errors often generate nonwords, a string of phonemes that do not constitute a real word (e.g. 'music' repeated as /pæntriːd/). Nonwords are produced across different communicative tasks and contexts, often dominating spoken output and causing significant communication difficulties for the person with Jargon aphasia. However, clinical intervention targeting nonwords in Jargon aphasia yields inconsistent or minimal improvement and nonword production persists (Bose, 2013; Bose, Höbler, & Saddy, 2019; Panzeri, Semenza, & Butterworth, 1987; Robson, Marshall, Pring, & Chiat, 1998). For some individuals with Jargon aphasia, nonword errors produced in close context to one another display high phonological similarity. For example, on a task of single word reading with one word consecutively after the other, target word 11., 'venture' was repeated as /viːtrʌs/, target word 12., 'despair' was repeated as /tiːpaʊlz/, target 13., 'tuck' as /truːɪz/, target word 14., 'pioneer' elicited /triːəs/ and target 15., 'cult' as /triːfels/. These consecutive errors display high phonological similarity, referred to as recurrent perseverations (Sandson & Albert, 1984; Santo Pietro & Rigrodsky, 1986).

Perseveration is the term used to describe erroneous repeated actions and has different forms and manifestations (Hudson, 1968). The recurrent form, most commonly reported in aphasia, is described as the repeated production of a previous action or output. In phonological and Jargon aphasia this manifests as the repetition of words or parts of previously produced words (Buckingham, Avakian-Whitaker, & Whitaker, 1978; Moses, Nickels, & Sheard, 2007). There is also 'stuck in set' perseveration, which is linked with executive functioning impairment and inappropriate task maintenance. The third major form of perseveration is termed 'continuous perseveration', which has been associated with basal ganglia damage and linked with motor action maintenance. One example of continuous perseveration is the continued drawing of a circle following task completion, sometimes described in Parkinson's disease (Helm-Estabrooks, Ramage, Bayles, & Cruz, 1998; Sandson & Albert, 1984). Despite the Sandson and Albert classification criteria, separating observed manifestations of perseverations into their different sub-types is not straight forward. In Sandson and Albert's classification they differentiate between the recurrent and continuous perseverations with the former attributed to problems inhibiting memory traces and the latter attributed to a disturbance to motor output which is associated with basal ganglia damage. However, there exists very limited experimental evaluation of the cognitive causes underpinning perseveration. Moses, Nickels and Sheard (2004) present individual KVH who presents with Jargon aphasia and produces recurrent perseverations in that he repeats parts of words and sometimes whole nonword items when responding to single word production tests. KVH is described as presenting with basal ganglia damage, which according to the Sandson and Albert criteria would indicate that he more likely presents with continuous perseveration which may be motivated by motor difficulties; however, Moses et al., (2004) suggest that his perseverations are recurrent in nature, based on the production of phonological perseverations. However, it is possible that motor factors may contribute to repeated patterns of phonological error, in that phonemes which are phonetically less complex may be favoured for production. Thus, the presence of phonological perseverations in output does not comprehensively rule out other forms of perseveration. The current study will not attempt to delineate the different forms of perseveration, but rather, will analyse patterns of erroneous repetitions of phonological segments in word production. These will be referred to as perseverations from herein.

Originally, perseverations were thought to occur from uninhibited memory traces. By this theory, after a word has been produced the memory trace of the word and/or sounds is maintained, preventing new words or phonemes from being processed appropriately and causing involuntary reproduction of previously produced words (Hudson, 1968; Papagno & Basso, 1996; Sandson & Albert, 1984). Perseveration errors are more commonly observed in people with severe forms of aphasia and both whole and part word responses can be perseverated. Part-word perseverations are sometimes called blended perseverations and are thought to occur when a newly encoded word mixes with a previous response and an amalgamation of both responses is produced (Buckingham, Avakian-Whitaker, & Whitaker, 1978). In Jargon aphasia the majority of perseverations are blended and comprise parts of previously produced responses, with perseverations often generating nonword errors and co-existing alongside non-perseverative nonword errors (Eaton, Marshall, & Pring, 2010; Pilkington et al., 2017). The nature of perseveration has been interpreted as a diagnostic marker of the underlying processing deficit and is therefore informative in diagnosing the form of aphasia, and additionally, in furthering our understanding of language processing and impairment in aphasia. Whole word perseverations are considered to reflect lexical selection deficits, with whole word representations overriding new lexical representations. Partial perseverations, such as those observed in Jargon aphasia, suggest phonological encoding breakdown, where phonological segments of the new target become contaminated by phonological segments from previous productions (Martin & Dell, 2007; Moses, Sheard, & Nickels, 2007; Stark, 2007). Perseverative and non-perseverative errors tend to co-occur and the relationship between these two forms of error has been used to demonstrate that there exists a common underlying source, suggesting that perseveration is a symptom of aphasia and manifests as a result of inability to adequately process new information (Cohen & Dehaene, 1998; Martin & Dell, 2004). Error patterns in Jargon aphasia support this interpretation, as the impairment is associated with impaired phonological processing and both perseveration and nonword errors comprise phonological nonword errors and partial perseverations (Buckingham & Buckingham, 2011; Pilkington et al., 2017).

5.1.2 Causes of Jargon and perseveration

5.1.2.1 Faulty Inhibition account

Original accounts of perseveration lacked clear theoretical frameworks, however recent computational and experimental studies have examined perseveration accounts within word selection and lexical access frameworks (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Martin & Dell, 2007; Fischer-Baum & Rapp, 2012). The traditional account of perseveration, implicating sustained memory traces, has been more recently labelled inhibition failure. Here, the term inhibition is used to refer to a unit turning off after production (Fischer-Baum & Rapp, 2012). This theory was derived from observations of patient behaviour, as some participants with aphasia appeared to lack the ability to produce a different response or output (Albert & Sandson, 1986; Helm-Estabrooks et al., 1998; Sandson & Albert, 1984). Theoretically, faulty inhibition would elicit this pattern and create series of perseverations. For example, on saying a word, the activation of that representation would remain heightened such that it would interfere and override the next word, generating a perseveration. Following this repeated re-production, activation would again be heightened and again interfere with subsequent processing, meaning the original word is again reproduced. Therefore, by the faulty inhibition account, previously used units (words or sounds) would continually impede processing of new information, significantly restricting output and producing long series of perseverations. There exist a small number of studies providing experimental evidence for this theory (Fischer-Baum & Rapp, 2012; Yamadori, 1981) and behavioural patterns consistent with this interpretation are reported in severe cases of Jargon aphasia (Pilkington et al., 2017). However, this theory cannot explain non-perseverative error productions which are usually observed in similar numbers to perseverative errors in Jargon aphasia, suggesting that a separate error mechanism is contributing to phonological perseveration.

5.1.2.2 Impoverished activation account

The most favoured account of phonological error in Jargon aphasia postulates that target sound segments are insufficiently activated, thereby allowing other sources of activation to out-compete target units (Hirsh, 1998; Martin & Dell, 2007). Potential sources of alternative activation include intrinsic noise or residual activation at previously produced units. Heightened activation post-production, referred to as residual activation, is a normal part of processing and has been evidenced in priming and reaction time studies which demonstrate that words are produced more quickly when they have been executed previously, demonstrating that less activation (indexed in this case by time) is required to achieve production when a unit has residual activation (Vitkovitch & Humphreys, 1991). This indicates that residual activation is a source of competition during subsequent processing, and under certain conditions, it will override target units that are weakly activated and generate a perseveration. This account has been further supported by computational studies of word processing, which manipulate the amount of activity at different units within a computerised lexical network (semantics, lexical, and phonological). To test the impoverished activation account, the rate of post-activation decay is controlled whilst the amount of activation within the network is varied, and the simulated errors are compared against errors obtained from people with aphasia. The activation within the simulated lexical network can be further manipulated, such that weak activation affects lexical or phonological processing separately, simulating impairments in word and phoneme selection, respectively. The errors generated under these conditions have been shown to align with whole word and blended perseverations observed in different types of aphasia, supporting the impoverished activation account of error and perseveration (Dell, Martin, & Schwartz, 2007; Dell et al., 1997). These models have successfully simulated nonword and perseveration patterns produced by people with phonological aphasia, demonstrating that nonword error and perseveration can arise when phonological units do not receive sufficient activation (Gotts, della Rocchetta, & Cipolotti, 2002; Schwartz, Saffran, Bloch, & Dell, 1994; Schwartz, Wilshire, Gagnon, & Polansky, 2004; Wilshire & McCarthy, 1996).

5.1.3 Alleviating Jargon and perseverations

To further evaluate the underlying sources of nonword error and perseveration in aphasia, a small number of studies have attempted to 'treat' or manage verbal perseverations and reduce phonological error by applying manipulations that target the impoverished activation and faulty inhibition accounts. Chapter 4 of this thesis examined the impoverished activation account of Jargon and perseveration by manipulating the psycholinguistic properties of target words to generate testing words sets that had either high or low lexical availability. The high availability words were easier to access and associated with greater lexical-semantic activation than the low availability word set with psycholinguistic properties frequency, imageability, concreteness and familiarity used as indexes of lexical availability. This manipulation is similar to the computational accounts which vary the amount of activation transferring from higher level processes (lexical selection) to phonology, and it was hypothesised that the more available target words would elicit greater accuracy and less perseveration, in line with existing computational accounts (Ackerman & Ellis, 2007; Corbett, Jefferies, & Ralph, 2008; Gotts et al., 2002; Pate, Saffran, & Martin, 1987). However, in chapter 4, this pattern was only consistently observed in three of the ten Jargon participants. Additionally, some participants showed lexical effects in their phonological accuracy but not their perseveration, and vice versa, suggesting that perseveration may be underpinned by a separate mechanism to other forms of phonological error. Results from chapter 4 are not the only Jargon reports failing to demonstrate consistent support for the impoverished activation account of perseveration. For example, Eaton, Marshall and Pring (2010) describe two individuals with Jargon aphasia who produce nonword errors and perseverations. Their perseveration errors occur either within close temporal context to a source, or across testing days and times; only the former conforms to the impoverished activation account of perseveration. Moses Nickels and Sheard (2004) describe similar word production patterns by participant KVH who produced high numbers of phonological perseverations at a lag of one trial alongside whole nonword item perseverations. Whilst competition from residual activation can explain perseverations across adjacent production trials, it cannot account for perseverations across testing sets and days. These long distance/temporal perseveration patterns suggest a more global mechanism might underpin some forms of perseveration, characterised by default or idiosyncratic phonological selection.

To target the delayed inhibition mechanism, the time/task immediately after word production has been manipulated, under the assumption that increasing the time in between word production trials allows for more complete inhibition. This should reduce competition between previously produced phonemes and the newly encoded targets. In healthy speakers, deadline production tasks have been used to demonstrate that less time for decay post-production increases error in the subsequent production trial (Moses, Nickels, & Sheard, 2004b; Vitkovitch & Humphreys, 1991). For example, Santo-Pietro and Rigrodsky (1982) demonstrate that perseverations were more likely when people had only a one second interval between trials, in comparison to a ten second inter-trial interval where significantly fewer perseveration errors were made. Gotts, della Rocchetta, & Cipolotti (2002) attempted to replicate this finding with aphasic individual EB, but their fast (one second) and slow (fifteen seconds) inter-trial intervals did not elicit different numbers of perseverations; however, EB was more errorful in the fast trial delivery condition. Corbett, Jefferies and Lambon-Ralph (2008) also manipulated stimulus presentation rate, but this did not influence either number of accurate responses or perseveration in their single case study of LS. A possible confound with the blank pause condition is that it provides opportunity for continued rehearsal or consideration of a previous error response, which would limit the decay rate. A conference paper by Kohen et al., (2012) explored this in more detail, by comparing a filled the interstimulus interval with a time-matched blank one. Fourteen people with aphasia completed a word repetition task with a counting aloud interstimulus task and a blank five second interstimulus interval. Eleven of the fourteen participants produced more perseveration on the filled trial condition, suggesting that the verbal rehearsal inter-trial task interfered with inhibition. This implies that the additional verbal material in between target words contributed to the maintenance of previous material which increased the likelihood that it would intrude on the subsequent trial. It is also possible that switching between repetition and counting required more time/focus than was allocated, and that the manipulation interfered with the encoding and activation of the new stimulus, such that the target word was consistently weakly encoded, creating bias towards residually activated units. Switching between word repetitions and counting will increase demands on cognitive control and inhibition, therefore the increase in perseveration may arise as a result of reduced cognitive control in addition to linguistic demands (Stark, 2017). Further information on switching ability is required to better understand the effect of this manipulation, and tests applying non-linguistic tasks as inter-stimulus manipulations may be more promising for reducing perseverations.

5.1.4 The current study

The current research study examines whether Jargon aphasia production can be manipulated by implementing tasks which target the inhibition mechanism/time period. To do this, single word reading was administered under four different experimental conditions. The first condition was a standard reading task with test words read aloud consecutively, one after the other. The second condition allocated additional time in between reading trials to allow for more complete inhibition to take place. In the remaining two conditions, additional sensory information was presented within the inter-word time period to explore whether additional material can divert attention and reduce subvocal rehearsal, thereby creating a better environment for inhibition to take place. The non-linguistic material was visual in nature to align with the sensory input modality of the reading aloud task and there were two levels of cognitive demand; one presented visual information passively and the other required a decision and response in relation to visual stimuli. Different levels of cognitive demand were manipulated to identify whether inhibition can be manipulated by increased the cognitive focus away from prior linguistic material.

5.2 ***Methods***

5.2.1 Participants

5.2.1.1 Profiling aphasia type

Ethical approval for this study was gained from the School of Psychology and Clinical Language Sciences research ethics committee at the University of Reading (project approval code: 2016-064-HR). The current study details eight individuals (two female; age $\bar{x}$ = 73 years, σ = 9.0; time post stroke (months, $\bar{x}$ = 39, σ = 24.4, see Table 5.1) with Jargon like profiles characterised by production of nonword errors as the dominant error in single word production tasks and Jargon-like profiles in spoken production including impaired auditory comprehension, poor repetition with relatively preserved fluency. The Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan & Barresi, 2001) short form was used to characterise language profiles and overall the group pattern demonstrated impaired auditory comprehension, poor repetition and relative fluency (see Figure 5.1). Participants 3 and 8 displayed reduced fluency in relation to that typically reported in people with Jargon aphasia (See Figure 5.1). On connected speech assessment both participants produced output comprising short phrases of four or five items (including words and nonwords) and demonstrated occasional hesitation in production. Their remaining language profiles (impaired auditory comprehension and repetition) were significantly impaired, aligning with the typical Jargon profile. Furthermore, on single word production tasks both participants produce high quantities of nonword word error indicating Jargon aphasia (see Figure 2). All eight participants in the current study are also reported in Chapter 4 (see Participants) along with their lesion overlap profile at the group level. High lesion overlap was present in posterior brain regions, specifically the posterior portion of the superior temporal gyrus. Participants are ranked by the quantity of nonwords produced on experimental testing and are presented in this order throughout, with participant 1 producing fewest nonword errors and participant 8 producing the greatest number of nonwords. All participants gave informed consent to participate in the current study.

Table 5.1: Participant demographic information.

Participant code	Age (years)	Gender	Months post stroke
1	71	M	78
2	62	M	11
3	71	M	57
4	74	F	9
5	78	M	24
6	61	M	42
7	85	M	33
8	84	F	58

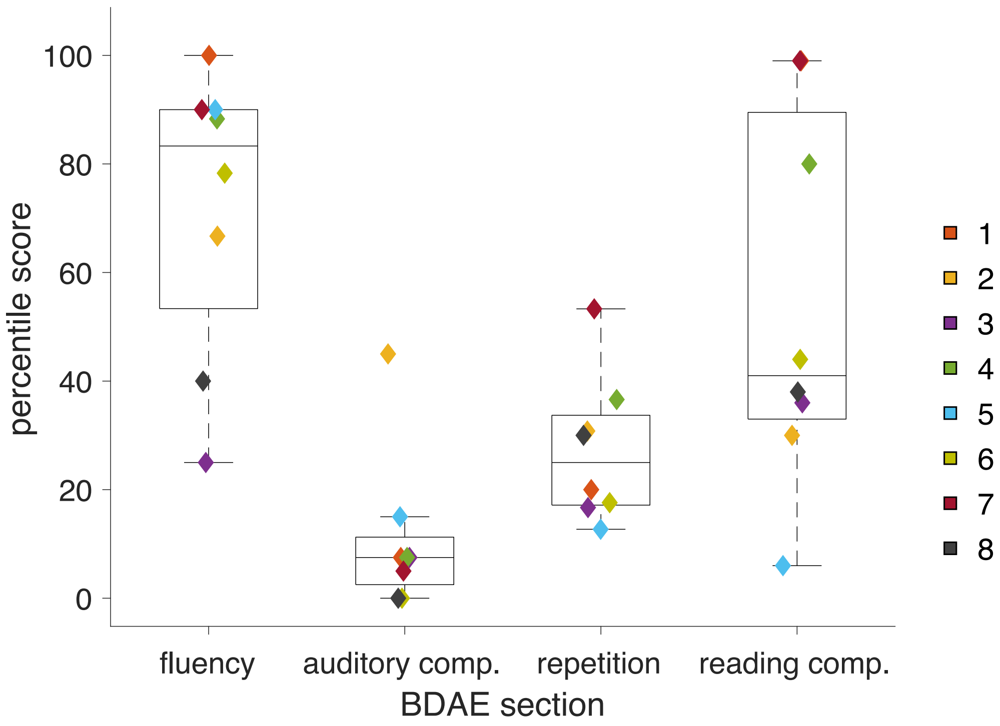


Figure 5.1: Boston Diagnostic Aphasia Examination short form percentile scores. Individual percentile scores are scatted over the boxplots, colour codes presented in legend. Reading comprehension includes symbol, letter, number, word-picture matching and sentence comprehension subtests.

5.2.1.2 Background testing

Participants completed tests of phonological, semantic, visual and executive processing. Written rhyme detection and initial phoneme segmentation subtests from the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1996) were used to profile phonological processing ability. Semantic processing was measured using the Camel and Cactus Test (CCT; Adlam, Patterson, Bozeat, & Hodges, 2010) and a synonym judgement task (96 synonym judgement; Jefferies, Patterson, Jones, & Lambon Ralph, 2009). Visual processing was assessed using two subtests from the Visual Object and Space Perception battery (VOSP, Warrington & James, 1991), including a screen test and a position discrimintation task. A grapheme matching task was developed and used to identify whether participants presented with significant impairments in processing letter shapes. In this task, participants were asked to match a probe grapheme, bigram or trigram to a target presented within an array of three distracters, presented in different fonts. The executive task (trail making) from the Oxford Cognitive Screen (Demeyere, Riddoch, Slavkova, Bickerton, & Humphreys, 2015) was administered as an index of switching ability. The first section requires participants to make a trail across triangles in descending size order, and the second section applies the same rules to circles. Participants are required to switch between the two shapes in the third trail while making the links in descending size order. Scores are reported separately for the non-switching and switching tasks according to successful connections made and a final executive score is calculated and used to identify presence of executive impairment. The first two trails (non-switching) have separate cut off scores of 5 and 5.95; for ease of interpretation these were collapsed and a conservative summary score of 10 was adopted. All participants passed the visual screening test from the VOSP; however, participant 5 performed below cut off in the position discrimination task. He also performed poorly on the grapheme matching task (see Table 5.2). Participants 5 and 8 were both identified as having a switching impairment according to their scores on the trail making (see Table 5.2).

Table 5.2: Participant raw and percentage( ) scores on semantic, phonological, visual and cognitive assessments.

Participant Code	Camel & Cactus	96 synonyms	Initial phoneme segmentation	Rhyme detection	Letter matching	VOSP(1)	VOSP(2)	Trail making 1	Trail making 2	Executive Score
1	59(92)*	91(95)*	22(49)*	47(78)	22(100)	20(100)	20(100)	12(100)	13(100)	-1
2	36(56)*	39(41)*	15(33)*	32(53)	22(100)	20(100)	20(100)	12(100)	10(77)	2
3	49(77)*	50(52)*	10(22)*	34(57)	22(100)	20(100)	20(100)	12(100)	13(100)	-1
4	51(80)*	84(88)*	23(51)*	32(53)	22(100)	20(100)	19(95)	12(100)	13(100)	-1
5	36(56)*	33(34)*	9(20)*	29(48)	10(45)	19(95)	16(80)*	12(100)	7(54)	5*
6	39(61)*	35(36)*	19(42)*	28(47)	21(95)	19(95)	19(95)	11(92)	13(100)	-2
7	48(75)*	91(95)*	9(20)*	46(77)	20(91)	18(90)	20(100)	12(100)	13(100)	-1
8	41(64)*	62(65)*	12(27)*	30(50)	21(95)	20(100)	20(100)	10(83)*	6(46)	4*
Cut offs	53(83)	92(96)	39(86)	-	-	15(75)	18(90)	10●	4(31)	4

*Note: 96 synonyms: 96 written synonym judgement; VOSP(1): Visual Object and Space Perception battery screening test; VOSP(2): Visual Object and Space Perception battery position discrimination; *scores below normative cut off; ● trail making 1 comprises two separate tests with cut offs of 5 and 5.85, we adopt a combined threshold of 10. – indicates normed cut-off data were unavailable.*

5.2.2 Tasks

5.2.2.1 Target words

Participants completed tasks of single word reading aloud. Target word sets were identical to those presented in the previous chapter. Originally there were two separate word sets, one with high lexical availability and the other containing words associated with lower lexical availability. The nonword error patterns observed across these word sets were analysed to determine whether the different lexical availability of the targets elicited significant differences in Jargon quantity. Results (reported in Appendix 9) indicated that Jargon quantity was not significantly different across the lexical conditions, therefore the two separate word sets were collapsed to generate one target word set consisting of 120 single words. For further information on the psycholinguistic properties of the target word sets see Appendix 6. The target word set of 120 items was presented once in each of the four trial formats.

5.2.2.2 Trial format

In the first trial format all words within a list were read aloud consecutively, one item immediately after the other. Following response completion, a fixation cross was presented for 1000ms. The fixation cross presentation was triggered by the experimenter when participant response was completed. This condition is labelled as Standard delivery (see Figure 5.2). The second trial format, labelled Pause, presented a fixation cross for an additional seven seconds in between each item in the target word list, generating a total inter-stimulus time period of 8 seconds. The pause was initiated when the prior verbal response was complete. The remaining two trial types involved the presentation of visual stimuli with different cognitive processing demands. In the third trial format, labelled as Passive, a pattern-reversing checkerboard was presented for seven seconds in between each target word. In the fourth trial format, labelled Active, an odd one out visual discrimination task was delivered. For this task, participants were presented with three Gabor masks, one of which had a different alignment to the other two (see Figure 5.2). Participants were instructed to respond by pointing to the odd one out.

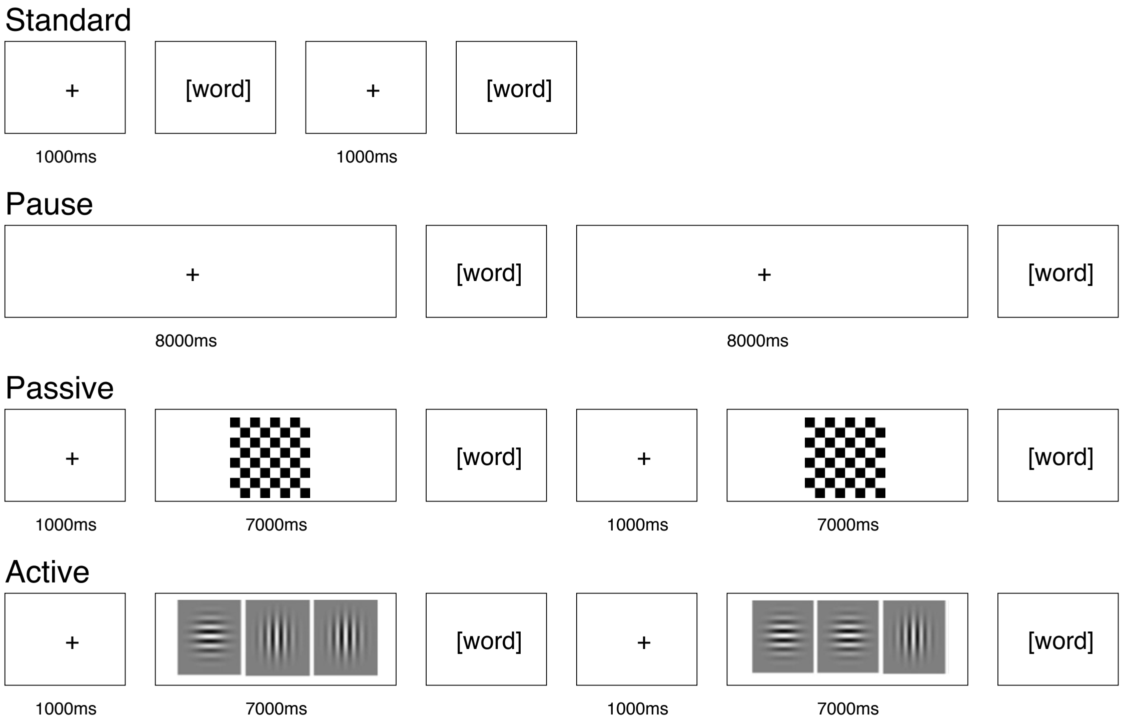


Figure 5.2: Pictorial representation of the Standard, Pause, Passive and Active trial formats. The standard trial format differs in timing to the remaining three trial formats.

5.2.3 Procedure

For data collection all participants were visited in their own homes by the first author. Target word set order was randomised across the different trial formats so that the Standard, Pause, Passive and Active formats each had their own word order. Each word set was presented on four separate occasions (as part of the Standard, Pause, Passive and Active trial formats) and to minimise practice effect there was a minimum of 14 days allocated in between presentations of the same target word. To accomplish this, data collection sessions included one word reading aloud task (which was either high availability or low availability) delivered in one of the trial formats (either Standard, Pause, Passive or Active) alongside one repetition task (data collected as part of a separate study not presented in this thesis) and one of the background tests (see Table 5.2). The following visit took place 7 days later and the opposing word set was administered (e.g. if high availability had been delivered in the previous session then low availability would be delivered in the following session) in a different trial format (e.g. in week 1 they completed the high availability words in the Pause format and in week 2 they completed the low availability words in the Active format) alongside a different repetition task and a different background test. The subsequent testing session took place a further seven days later where the same word set as delivered in week 1 (in this example the highly available words) would be presented in a different order in a different trial format. This approach to data collection was continued until all trial formats had been administered for both the high and low availability word sets. All data collection sessions were spaced out by a minimum of seven days which ensured that participants were not exposed to the same target word within a 14 day period to minimise practice effects.

All stimuli were presented via laptop computer using E-Prime and participants were instructed to read the target word aloud to the best of their ability. No feedback was provided on accuracy of participant performance. However, participants were moved onto the next target word following three unsuccessful attempts at response production. The experimenter had control over experiment timing and moved participants onto the next trial/task using the spacebar. Participant responses were transcribed in real time using broad phonemic transcription and an audio recording was taken and subsequently used to confirm transcriptions were correct. Response transcriptions were converted to DISC symbols which have 1:1 phoneme-symbol correspondence (e.g. /u:/ = u) to enable automated analysis of phonological accuracy and perseveration using Microsoft Excel.

5.2.4 Analyses

5.2.4.1 Error analysis

5.2.4.1.1 Response categorisation

Responses were coded based on criteria presented in Dell et al., (1997). Non-lexical errors (a string of phonemes that do not constitute a word in the English language) were identified as nonwords. Where participants had produced no spoken response to a target word or indicated that they did not know, a non-response was recorded. Where a real word error had been produced it was coded as either a formal error (if phonologically related to the target in either initial phoneme or it contained 50% target phonology), an unrelated error (no semantic or phonological relationship to the target), a semantic error (related in meaning to the target word) or a mixed error (demonstrating both a semantic and phonological relationship to the target). Error patterns were inspected to confirm that nonword errors were the dominant form of erroneous production.

5.2.4.2 Trial format impact on Jargon

Data were collapsed across the high and low word sets to create a single word set of 120 items. For the case series analysis individual chi-square goodness-of-fit tests were used to examine whether the number of nonwords differed under the different trial formats (Standard, Pause, Passive, Active).

5.2.4.3 Phonological accuracy analysis

The quality of responses was measured using the Phonological Overlap Index (POI; Schwartz et al., 2004). Measures of response quality are useful for this patient population since errors have been observed to contain a range of accuracy, with some errors sharing only one or two target phonemes (e.g. target word 'crush' read as /riːnəʊ/) and others containing greater amounts of target phonology (e.g. target word 'receipt' read as /jəsiːp/). The POI measure generates a statistic between zero and one, indicative of how phonologically accurate a response is and thus, is sensitive to such within response variation. A value of zero identifies that no target phoneme segments were produced in the response and a value of one demonstrates that all target phonemes were present, and no other non-target phonology was produced. The formula for the POI statistic is:

$$\text{POI} = \frac{\textit{(number of phonemes shared between response and target) x2}}{\textit{total phonemes in target + total phonemes in response}}$$

Non-responses were removed from this analysis meaning that any POI score of zero indicated that a verbal response has been produced but did not contain any target phonology. All remaining responses were included in this analysis (including correct responses which earn a POI score of 1). By this approach, results from this analysis provide a metric of overall phonological production accuracy. To identify whether phonological production changed across the Standard, Pause, Passive and Active trial types, a one-way repeated measures ANOVA was implemented with average POI per participant entered for each of the four trial types. For the case series analysis, the majority of POI data did not conform to the normal distribution, therefore non-parametric one-way repeated measures (Friedman's) ANOVAs were used to determine whether there was an effect of trial type (Standard, Pause, Passive, Active) on phonological accuracy (POI) at the individual level. Where a significant effect of trial type was identified, post hoc analyses were implemented using Wilcoxon signed rank tests to determine which levels of the trial type had given rise different degrees of phonological accuracy and Bonferroni-Holm correction was applied to account for the six different post-hoc comparisons.

5.2.4.4 Phoneme perseveration analysis

Phoneme perseveration was measured using an analysis based on that presented in Martin and Dell (2007). For every response, all phonemes that had been produced in error were identified. For example, in response to the target word 'siege' participant 6 gave the response /sʊlɪts/, producing phonemes /ʊ l ɪ t s/ in error. Each error phoneme was then searched for within the immediately preceding response. In the example, /prəʊts/ was the preceding response. This production contains /t/ and /s/ from the /sʊlɪts/ response error phonemes. Where an error phoneme had been produced in the response immediately preceding it, as with /t/ and /s/ in the example, these errors were recorded as phoneme perseverations. The total number of phoneme perseverations in each response was summed and then divided by the total phonemic length of the response. In the example, this would result in two phoneme perseverations divided by five, resulting in a perseveration score of 0.4, reflecting that response /sʊlɪts/ was 40% perseverative. In the current analysis, only phoneme perseverations from the immediately preceding response were identified to minimise the probability of matching phoneme errors in previous responses by chance. This method yields a perseveration score between zero and one for each response, with zero indicating that a response had no perseverated phonemes in it and one indicating that every phoneme in that response was an error and was also produced in the immediately preceding response. Nonresponses were removed from this analysis so that a perseveration score of zero always refers to a verbal response that did not contain any phoneme perseverations. The first response was also excluded from this analysis since there was no preceding production.

To identify whether phoneme perseveration changed across the standard, pause, passive and active trial types, a one-way repeated measures ANOVA was implemented with the average perseveration score per participant entered for each of the four trial types. For the case series analysis, the majority of participant data violated normality, therefore non-parametric one-way repeated measures (Friedman's) ANOVAs were used to determine whether there was an effect of trial type (standard, pause, passive, active) on perseveration. Where a significant effect of trial type was identified, post hoc analyses were implemented using Wilcoxon signed rank tests to determine which levels of the trial type had generated different perseveration rates. Bonferroni-Holm correction was applied to account for the six different post-hoc comparisons.

5.3 ***Results***

5.3.1 Error analysis

5.3.1.1 Collapsing across word sets

Responses were labelled as either correct, nonwords, formal, unrelated, semantic, mixed or a non-response. Full error data for each participant across the high and low availability word sets and trial formats is presented in Table 5.3. Inspection of error patterns demonstrated that nonwords were the most common error type for all participants (see Table 5.3, Figure 5.3). They were also the most common response type for everyone except participant 1 who was the most accurate participant, producing an average of 51% correct response and 42% nonword errors (see Table 5.3). Participant 1 produced the smallest proportion of nonword responses (42%) and participant 8 produced the greatest amount of nonword responses (95%; see Figure 5.3). Other error types comprised less than 12% of response types for all participants apart from participant 3 who produced other types of error 25% of the time (see Table 5.2). His other error forms consisted of real words that shared word initial phonology with the target word (e.g. target word 'oath' read aloud as 'opened') or real words responses with no obvious target relationship (e.g. target word 'animal' read aloud as 'understand').

Table 5.3: Participant responses produced across the trial formats. Observed numbers (percentages) presented.

		Participant code							
Response type	Trial format	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Correct	Standard	66(55)	26(22)	2(2)	2(2)	0(0)	1(1)	1(1)	0(0)
	Pause	64(53)	35(29)	2(2)	1(1)	0(0)	2(2)	3(3)	0(0)
	Passive	60(50)	48(40)	3(3)	2(2)	0(0)	1(1)	2(2)	0(0)
	Active	56(47)	46(38)	1(1)	1(1)	0(0)	3(3)	3(3)	0(0)
Nonwords	Standard	44(37)	73(60)	81(68)	105(88)	116(96)	108(90)	113(94)	118(98)
	Pause	50(42)	70(58)	96(80)	107(89)	105(88)	103(86)	105(88)	115(96)
	Passive	49(41)	59(50)	88(73)	104(87)	106(88)	105(88)	108(90)	118(98)
	Active	57(48)	61(51)	84(70)	102(85)	116(97)	104(87)	106(88)	103(86)
Formal	Standard	10(8)	11(9)	25(21)	3(3)	1(1)	6(5)	3(3)	0(0)
	Pause	6(5)	12(10)	9(8)	8(7)	1(1)	6(5)	4(3)	0(0)
	Passive	8(7)	9(8)	20(17)	7(6)	2(2)	4(3)	2(2)	0(0)
	Active	7(6)	10(8)	20(17)	6(5)	1(1)	5(4)	7(6)	0(0)
Unrelated	Standard	0(0)	7(6)	12(10)	10(8)	3(3)	4(3)	3(3)	2(2)
	Pause	0(0)	3(3)	13(11)	3(3)	14(12)	8(7)	8(7)	3(3)
	Passive	2(2)	4(3)	9(8)	7(6)	12(10)	8(7)	8(7)	0(0)
	Active	0(0)	3(3)	15(13)	11(9)	3(2.5)	8(7)	4(3)	10(8)
Semantic	Standard	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	Pause	0(0)	0(0)	0(0)	0(0)	0(0)	1(1)	0(0)	0(0)
	Passive	1(1)	0(0)	0(0)	0(0)	0(0)	2(2)	0(0)	0(0)
	Active	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Mixed	Standard	0(0)	3(3)	0(0)	0(0)	0(0)	1(1)	0(0)	0(0)
	Pause	0(0)	0(0)	0(0)	1(1)	0(0)	0(0)	0(0)	0(0)
	Passive	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	Active	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Non-response	Standard	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
	Pause	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(2)
	Passive	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(2)
	Active	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	7(6)

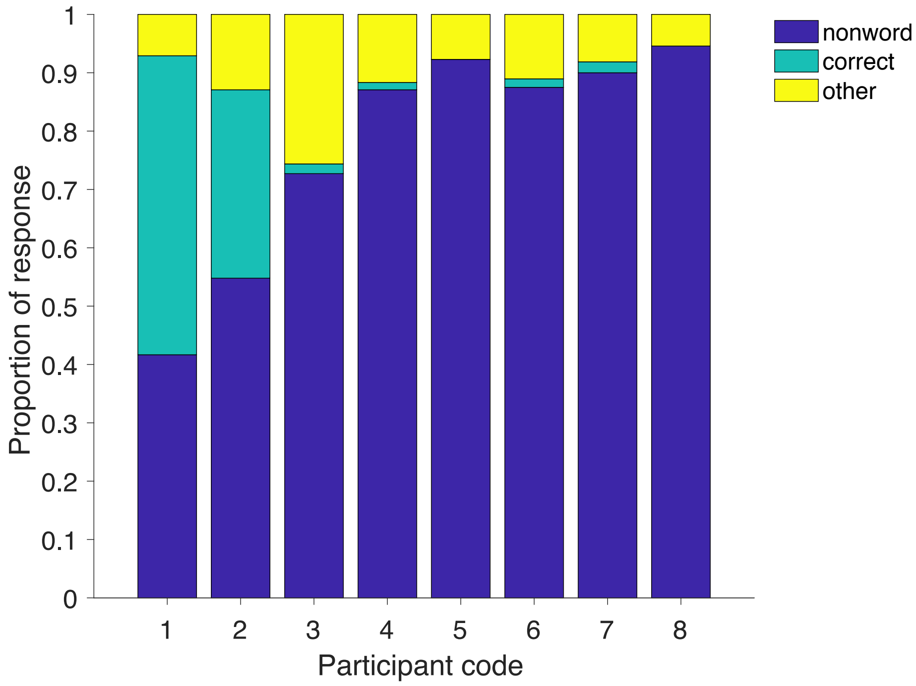


Figure 5.3: Proportion of nonword, correct and other response types produced on single word reading tasks.

5.3.1.2 Trial effect on Jargon

Chi-square goodness of fit tests were used to examine whether trial format (standard, pause, passive, active) influenced nonword quantity at the individual level. The number of nonwords observed across the different trial types was not statistically different for all eight participants ($p \geq .632$, see Table 5.3, Table 5.4)

Table 5.4: Chi square test statistic and significance value for effect of trial type on nonword quantity.

Pt. code	Chi square	df	*p*
1	1.72	3	0.632
2	2.11	3	0.549
3	1.45	3	0.693
4	0.12	3	0.988
5	1.00	3	0.801
6	0.13	3	0.987
7	0.35	3	0.950
8	1.35	3	0.717

5.3.2 Trial effect on phonological accuracy

5.3.2.1 Group analysis

Phonological accuracy of responses was quantified using the Phonological Overlap Index (POI) which derives a score between zero and one for each response with one representing complete phonological overlap between response and target and zero representing no phonological overlap. A one-way repeated measures ANOVA was used to analyse whether there was an effect of trial format (Standard, Pause, Passive, and Active) on phonological accuracy of production at the group level. The ANOVA identified that there was no statistical difference in production across the different trial formats ($F(1.257, 8.978) = 1.954$, $p = .199$, $\eta p^2 = .218$, see Figure 5.4; Greenhouse Geiser reported as sphericity violated).

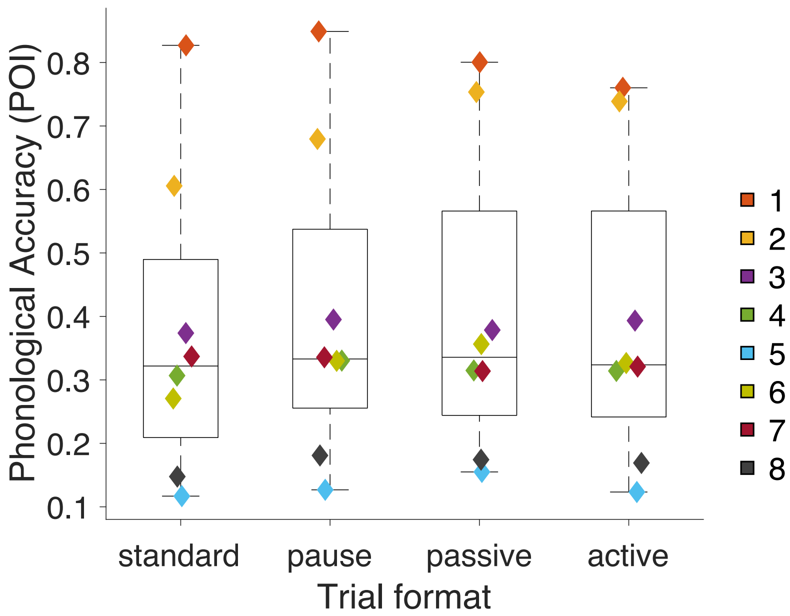


Figure 5.4: Phonological accuracy of production across the different trial formats. Boxplots represent group distribution and individual markers indicate participant means.

5.3.2.2 Case-series analysis

A one-way non-parametric (Friedman's) ANOVA was used to analyse whether the different type of trial format (Standard, Pause, Passive, Active) influenced phonological production accuracy (POI) of production for each participant. The Friedman's ANOVAs identified that there were no effects of trial type on phonological accuracy (POI) for five participants (3, 4, 5, 7 and 8; $\chi^2(3) \leq 7.441$, $p \geq .059$, see Table 5.5, Figure 5.5). Participants 1, 2 and 6 showed significant effects of trial type on their phonological accuracy ($\chi^2(3) \geq 10.95$, $p \leq .012$).

Table 5.5: Chi-Square statistic and p value from Freidman ANOVA analysing effect of trial format on phonological production accuracy.

Pt. code	N	Chi-Square	df	*p*
1	120	20.676	3	≤ .001
2	120	17.832	3	≤ .001
3	120	1.777	3	.620
4	120	0.993	3	.803
5	120	7.441	3	.059
6	120	10.951	3	.012
7	120	1.752	3	.626
8	109	2.141	3	.544

Post hoc Wilcoxon signed ranks with Bonferroni Holm correction were used to identify which trial type affected phonological accuracy. Participant 1 was least accurate in the Active trials ($\mu = 0.76$, $\sigma = 0.26$; see Figure 5.5.1) and this was statistically lower than accuracy observed in the Standard ($p = .003$) and the Pause ($p \leq .0001$) trials. The Passive trial type also elicited lower phonological accuracy than the Pause condition ($p = .008$). Remaining comparisons for participant 1 did not reach corrected significance. Participant 2 was least accurate in the Standard trial ($\mu = 0.61$, $\sigma = 0.31$; see Figure 5.5.2) and this was statistically lower than accuracy observed in the Passive ($\mu = 0.75$, $\sigma = 0.26$, $p \leq .0001$) and Active ($\mu = 0.74$, $\sigma = 0.29$, $p = .002$) trial types. Production in the Pause trials ($\mu = 0.68$, $\sigma = 0.27$) was less accurate than production in the Passive trials ($p = .009$). Participant 6 was least accurate in the Standard trials ($\mu = 0.27$, $\sigma = 0.20$) and most accurate in the Passive trials ($\mu = 0.36$, $\sigma = 0.23$) and the difference between these two trial conditions was statistically significant ($p = .0004$).

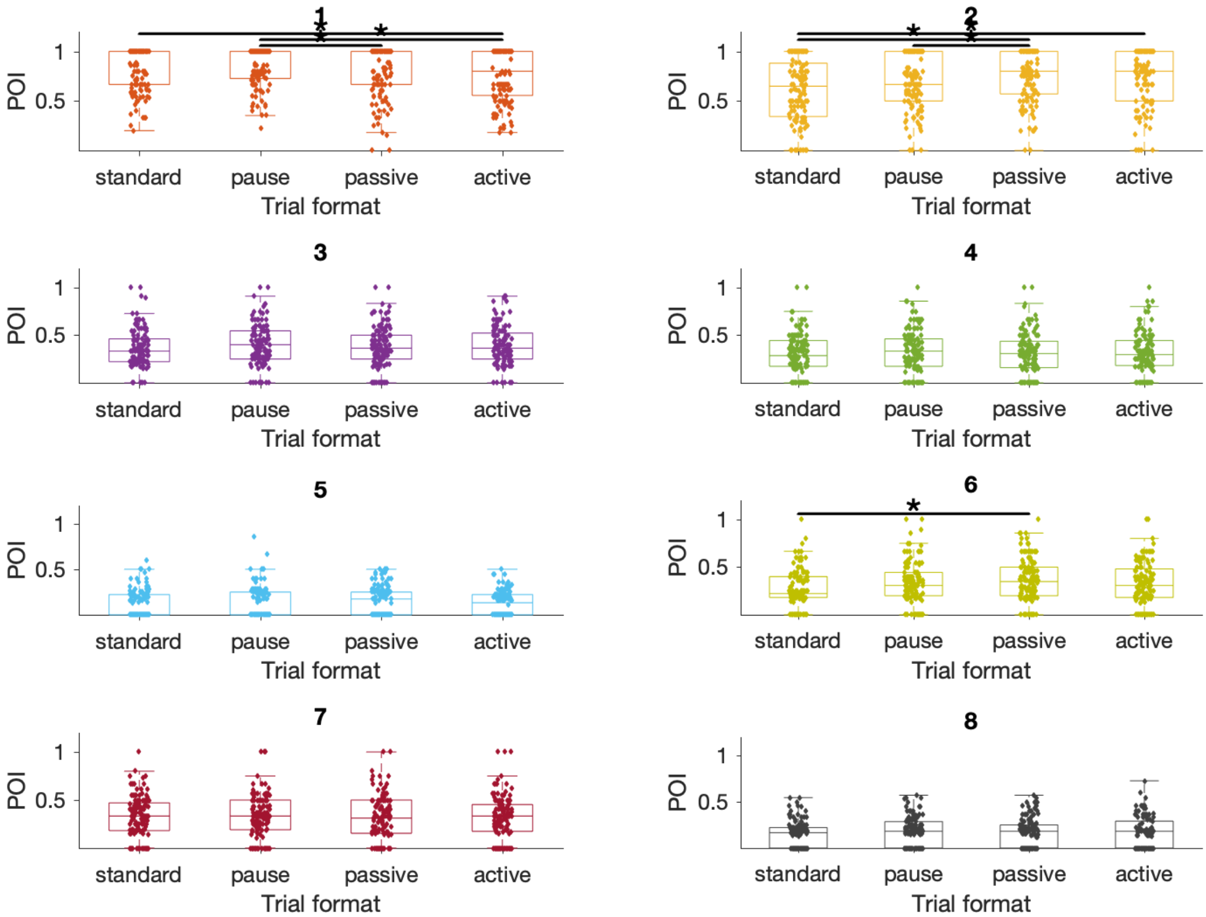


Figure 5.5: Phonological Overlap Index (POI) distributions for standard, pause, passive and active trial types. Stars indicate significant differences when Bonferroni-Holm correction applied.

5.3.3 Perseveration

5.3.3.1 Group analysis

Individual phoneme errors in all responses were categorised as perseverative if they were also produced in the immediately preceding response. The perseveration score was calculated by dividing the number of perseverated phonemes in a response by the total phonemic length of that response. Non-responses were removed from the data for this analysis to ensure that a low perseveration score indexed verbal productions that were not perseverative. A one-way repeated measures ANOVA was used to analyse whether there was an effect of trial format (Standard, Pause, Passive, and Active) on phoneme perseveration at the group level. The ANOVA identified that there was no statistical difference in perseveration across the different trial formats ($F(3, 21) = 2.07$ $p = .135$, $\eta p2 = .228$, see Figure 5.6).

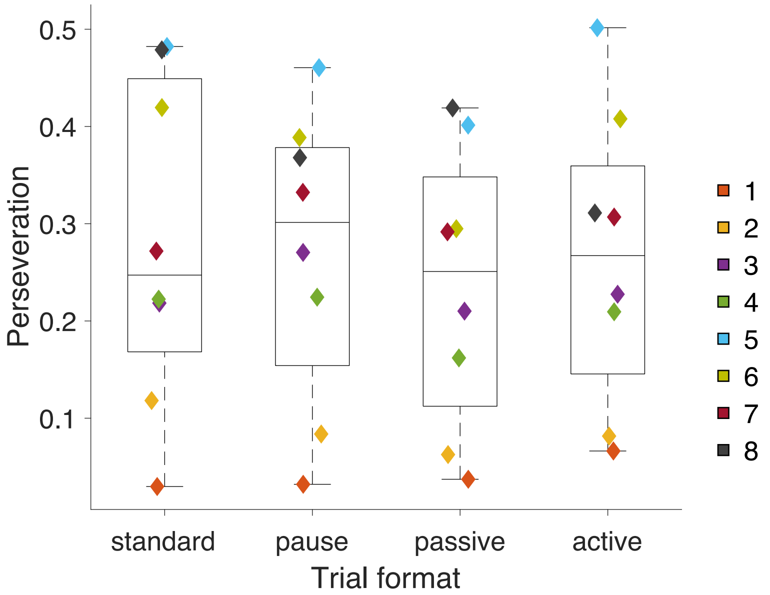


Figure 5.6: Participant perseveration across the different trial formats. Boxplots represent group distribution and individual markers indicate participant means.

5.3.3.2 Case-series analysis

Non-parametric ANOVAs (Friedman's) were used to examine whether there was a significant effect of trial format (Standard, Pause, Passive, and Active) on phoneme perseveration. Results demonstrated that participants 5 ($p = .001$), 6 and 8 ($p \leq .001$) produced different rates of perseveration under the different trial formats (see Table 5.6). The remaining five participants produced similar rates of perseveration across the different trial formats ($p \geq .126$, see Table 5.6).

Table 5.6: Chi-Square statistic and p value from Freidman ANOVA analysing effect of trial format on perseveration.

Pt. Code	N	Chi-Square	df	*p*
1	112	4.51	3	.212
2	112	4.20	3	.241
3	112	4.37	3	.224
4	112	5.72	3	.126
5	112	17.53	3	.001
6	112	22.62	3	≤ .001
7	112	5.15	3	.161
8	101	21.64	3	≤ .001

Post hoc Wilcoxon signed ranks with Bonferroni Holm correction were used to identify which trial types impacted on perseveration for the three participants who demonstrated significant effects of phoneme perseveration under the different trial formats. Participant 5 was least perseverative in the Passive trial format (μ = 0.40, σ = 0.28) and this was statistically lower than perseveration rates observed in the Active (μ = 0.50, σ = 0.26, p = .002) and Standard trials (μ = 0.48, σ = 0.29, p = .006, see Figure 5.7.5). Remaining observations for participant 5 did not reach corrected significance. Participant 6 also produced the least phoneme perseveration on the Passive trial type (μ = 0.29, σ = 0.23), which was statistically lower than the perseveration produced on the three alternate trial formats ($p \leq .002$; see Figure 5.7.6). Participant 8 was most perseverative in the Standard trial format (μ = 0.48, σ = 0.25, see Figure 5.7.8) and this was greater than the rate of perseveration observed in both the Active format (μ = 0.31, σ = 0.23, $p \leq .0001$) and the Pause trial format (μ = 0.37, σ = 0.22, p = .001). The active trial format was also less perseverative than the Passive format (μ = 0.42, σ = 0.22, $p \leq .0001$). The remaining post-hoc comparisons for participant 8 were not statistically significant.

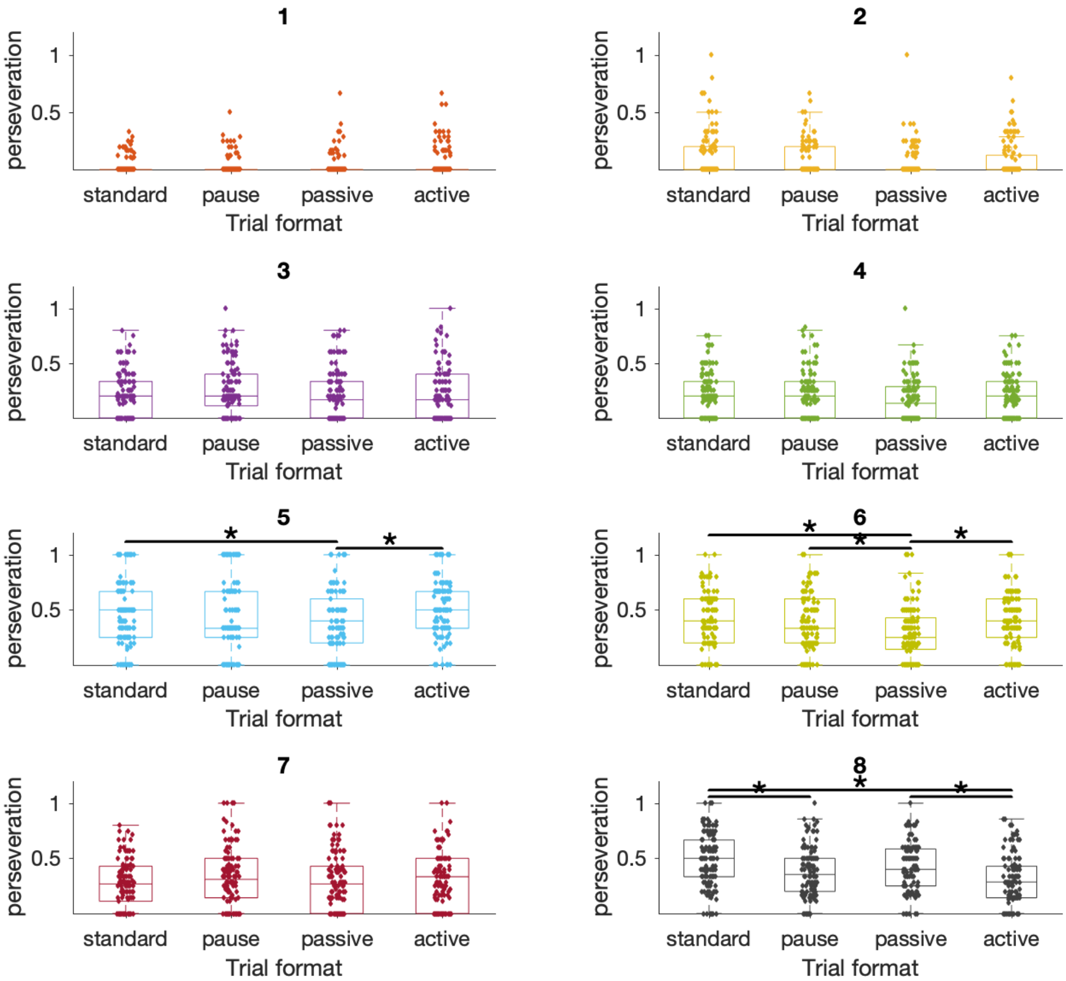


Figure 5.7: Perseveration scores observed across the standard, pause, passive and active trial types. Stars indicate significant differences when Bonferroni-Holm correction applied.

5.4 ***Discussion***

Jargon aphasia is an acquired language disorder associated with severe phonological error in spoken production and phoneme perseveration (Buckingham et al., 1978; Lecours, Osborn, Travis, Rouillon, & Lavall´E-Huynh, 1981). These errors are thought to occur when phonological segments belonging to a target word are insufficiently activated and/or when post-production inhibition is delayed (Dell et al., 1997; Schwartz, Dell, & Martin, 2004). Both error mechanisms increase the competition between present and previous productions; poor activation of a target means that post-production decay is likely to out-compete the current target, whereas reduced inhibition would bias processing towards previously used segments, irrespective of the degree of target activation (Cohen & Dehaene, 1998; Fischer-Baum & Rapp, 2012). Numerous studies document error and perseveration patterns aligning with the impoverished activation account; however, fewer find evidence supporting the reduced inhibition account (Eaton et al., 2010; Gotts et al., 2002; Hirsh, 1998; Moses et al., 2004a). The current study applied time and task manipulations in single word reading aloud paradigms to explore whether inhibitory processing contributes to the Jargon aphasia and to analyse whether inhibition could be facilitated or manipulated by the use of non-linguistic stimulation. Eight people with Jargon aphasia completed tasks of single word reading aloud under four different experimental conditions. The first condition, labelled as Standard, required participants to read single words aloud one after the other. The remaining three conditions all had an additional seven seconds in between each target word, with the Pause condition presenting a fixation cross, the Passive condition presenting a pattern-reversing checkerboard and the Active condition presenting a visual odd-one-out discrimination task. Jargon production was quantified by the number of nonword errors produced, the phonological accuracy of responses, and the phoneme perseveration within responses. These three behavioural metrics were used to compare Jargon production across the four different trial formats, using group level and case-series analyses. Group level results demonstrated that Jargon production did not change under the different trial types across any of the behavioural measures. However, the case-series analyses identified a subset of participants who exhibited effects of different trial formats on their production accuracy and perseveration, suggesting that post-production decay rates contribute to error and perseveration in some people with Jargon aphasia.

The first inter-stimulus manipulation of trial format added seven seconds in between each word to examine whether greater time post production, allowing for more complete inhibition, led to improved production. Results from the current study identified that time alone (Pause) did not elicit significant production benefits over the standard delivery trial type, suggesting that delayed inhibition is not a significant contributor to Jargon production. Current results align with a case study report by Corbett et al. (2008) who demonstrated that perseveration in aphasia was not exacerbated by shorter inter-stimulus intervals for their participant with Transcortical Sensory Aphasia. A similar finding is reported by Gotts et al. (2002), who applied a 15 second inter-stimulus pause in between trials on a picture naming task for individual E.B and compared perseveration rates between this and a fast (one second) presentation rate condition. The motivation for applying a longer inter-stimulus interval stems from word production priming studies which demonstrate that production worsens, and perseveration increases when response times are shortened for healthy speakers (Moses et al., 2004b; Vitkovitch & Humphreys, 1991). In studies of aphasic production, shorter inter-stimulus intervals are applied after response completion, whereas the priming studies with healthy speakers apply pressure during response duration from the onset across much shorter time intervals. Application of response pressure biases production towards past productions in two ways; one, by limiting time for inhibition of prior productions, and two, by limiting time for encoding of new items. The inhibition mechanism was targeted in the current study by the addition of seven seconds; however, no time pressure was applied to stimulus encoding and thus, the activatory mechanism was not targeted in the current study. Therefore, the lack of effects in the current study (and reflected in the aphasia literature on perseveration) taken alongside the more consistent effects observed in priming studies suggest that impoverished activation may be more important in the generation of perseverations, in comparison to inhibition. To test this, reaction-time studies with aphasia are required; however, application of this manipulation is not straightforward in aphasia, as restricting reaction time for people who have even mild word production impairment leads to high proportion of non-response errors, restricting data usability.

Although time alone, reflected in the Pause condition, exerted little consistent influence over perseveration and production in the current study, the addition of material within the inter-stimulus interval appeared more effective, with current results demonstrating that the Passive and Active trial formats affected production for five of the eight participants. The Passive trial format, which presented a pattern-reversing checkerboard for seven seconds in between each target word, elicited the most accurate production for participant 2, increased accuracy and reduced perseveration for 6, and reduced perseveration for participant 5. The Active trial type, which required an odd-one-out visual discrimination decision over a seven second time period, elicited significantly less perseveration for participant 8 than the passive and standard conditions. These results suggest that phonological processing in Jargon aphasia can benefit from the presentation of non-linguistic material to focus attention away from previous phonology and minimise competition between past production and the current target item, creating a more optimal environment for phonological encoding. The Pause, Passive and Active trial formats differed in their attentional demands, with the Active task requiring the most active engagement and the Pause trial type requiring passive attention. The pattern of effects observed in this sub-group of participants suggests that switching between word production and attentional tasks which require moderate degrees of engagement are most effective in facilitating inhibition when presented as an inter-stimulus trial.

Trail making results (see Table 5.2) indicate that the three participants who showed no effects of the trial types over their production (participants 3, 4, & 7) obtained the maximum accuracy scores on the switching task (linking shapes by size and type). Accuracy on the switching task (trail making) indicates that inhibitory processing is sufficient to allow a switch in task and no effects across the trial formats suggests that the additional time/task did not alter inhibitory processing, implying that the production of these participants is not underpinned by delayed inhibition or a deficit in inhibiting previous material. For participants 1, 2, 5, 6, & 8, who demonstrated altered production under the different trial conditions, participants 5 and 8 were identified as having impaired ability to switch (see Table 5.2), whilst participants 2 and 6 also made errors on the trail making task, but their performance fell within the normal range. Together, this indicates that participants who performed at ceiling with the switching task showed no effects of trial format, whereas participants who demonstrated switching issues on the trail making task showed effects of the inter-stimulus manipulations. This suggests that people who were able to switch task without difficulty (indexed by the trail making) had sufficient inhibitory processing so as to support this behavioural switch, and their production did not benefit from the additional time (to allow for more complete decay) or task (to support focus away from prior material) manipulations because deficient inhibitory processing was not a significant part of their behavioural presentation. Participants who showed effects of the trial format manipulations were more likely present with impaired inhibitory processing as the additional tasks forced a switch away from previous material which was, otherwise, difficult to achieve, as indexed by their poorer performance on the trail making task. This indicates that some people with Jargon aphasia present with impaired switching and inhibitory processing and that this deficit is associated with their spoken production. Results from Chapter 4 further support this interpretation, as participants 5 and 6 (participants G and H in Chapter 4) demonstrated reverse frequency effects in their production, producing more perseveration and lower accuracy responses when target words were more available. Production being more impaired when words with greater activation patterns are processed may be explained by inhibitory deficits, in that words with stronger activation patterns are more difficult to inhibit and thus, people with inhibitory problems may have greater difficulty processing such words. In this chapter, both participants produced less perseveration in the Passive trial format, suggesting that more time and attention focus on alternate material encouraged more successful inhibition of phonology. This aligns with the interpretation that their production is associated with inhibitory deficits.

However, participant 1 contradicts this trend as his accuracy decreased as switching demands increased, exhibiting his lowest accuracy production in the Active trial format (see Figures 5 and 6) but obtaining the maximum score on the trail making task, indicating preserved switching ability. It is unclear why such a pattern may arise, and further work exploring switching abilities and other measures associated with executive functioning in Jargon aphasia would provide useful information and support interpretation of these patterns. Executive functioning has been described as relevant and possibly contributory in Jargon aphasia since the earliest reports of the disorder, and it continues to be a source of interest in Jargon aphasia (Kinsbourne & Warrington, 1963; Robinson, Butterworth, & Cipolotti, 2015; Weinstein, 1981). However, many existing measures of executive functioning components require advanced linguistic skill, limiting their validity with severe forms of aphasia. The development of low-linguistic executive task versions, such as the Oxford Cognitive Screen (Demeyere et al., 2015) allow for more accurate profiling of cognition in this participant group and should be used to explore executive functioning in people with aphasia to understand how broader cognitive functions affect the behavioural profile and to identify potential treatment approaches.

Clinical implications

Current results demonstrate that the standard delivery trial format was most likely to reduce accuracy and increase perseveration in the current group, implying that standard assessment and intervention approaches which often utilise single word paradigms may be the least facilitative for people with Jargon aphasia. On the contrary, presenting non-language material targeting passive attention was, overall, the most facilitative. This suggests that clinical intervention in Jargon aphasia may benefit from approaching word-production tasks differently, using non-linguistic tasks alongside more typical intervention approaches. Clinical assessment and intervention are heavily embedded within single word approaches; however, this approach may be counter-productive for patients with Jargon aphasia whose production can often be exacerbated by this approach.

5.5 ***Conclusions***

The current study demonstrated that Jargon production can be altered by the addition of inter-stimulus tasks designed to target post-production inhibition and that non-linguistic material presented in between single written words benefitted phonological production in a sub-group of participants. Participants within this sub-group displayed some degree of switching impairment, whereas participants who showed no effects of the inter-stimulus manipulations displayed preserved switching, indicating that inhibitory processes contribute to Jargon production and perseveration for some, but not all, people with Jargon aphasia.

Chapter 6. General discussion

6.1 ***Summary***

This thesis explored the cognitive-linguistic mechanisms underpinning word production deficits in Jargon aphasia. This discussion comprises three main sections. Firstly, results from the three experimental chapters (Chapters 3, 4, and 5) are summarised and discussed in relation to existing literature. These findings are then integrated and considered in relation to different theoretical positions to determine which account(s) best explain results from the experimental chapters. Secondly, the methodological strengths of this thesis are evaluated, with particular focus on the case-series approach which has featured heavily in all three studies. The third section of this discussion considers the clinical implications of this work for people with Jargon aphasia and future directions of this work and finally, an overall conclusion is presented.

6.2 ***Experimental chapter summaries***

6.2.1 Chapter 3: Cross-task analysis of Jargon production

This study considered how different theoretical positions associated with nonword error in Jargon aphasia could account for error patterns observed in word production tasks of repetition, reading and naming for ten people with Jargon aphasia. One of the major theories of nonword production in Jargon aphasia suggests that nonwords occur from a single phonological source of error, which affects the correctly identified target word representation (Dell et al., 1997; Kertesz & Benson, 1970, Hillis et al., 1999). However, the role of lexical selection mechanisms in Jargon aphasia is unclear, as some nonword errors bear little phonological resemblance to their target word, suggesting that phonological construction is completed without reference to the target word representation (Buckingham, 1990; Butterworth, 1979). This error profile has been explained by an alternate hypothesis which postulates that some errors occur when word access fails, and production comprises randomly selected phonological segments. Single word production tasks of auditory repetition, reading aloud and picture naming engage the word production system differently, with picture naming weighing more heavily on lexical and semantic processes whereas repetition and reading can be accomplished with additional support from bottom up processes and less weight on lexical-semantics. This task difference was used to probe the error mechanisms in Jargon aphasia, adopting a case-series design across ten people with neologistic Jargon aphasia. By the phonological hypothesis, error patterns should be similar across repetition, reading and naming, since all output tasks require phonological encoding for production, whereas a greater quantity and severity of nonword error observed in naming versus repetition/reading would suggest alternate, lexical-semantic contributions to error production in Jargon aphasia. This study compared nonword quantity and quality (phonological accuracy within nonwords) to evaluate whether phonological or lexical retrieval deficits could best explain the error patterns observed across participants. Phoneme frequency distributions within nonwords were also analysed to determine whether nonword phonological production patterns conformed to the typical distributions expected in English. Frequency distributions which aligned with typical pattern of English would indicate that nonwords are generated with lexical-phonological constraint and that the phonological system in Jargon retains its typical structure, whereas atypical phoneme distributions would imply nonlexical mechanisms were influencing nonword phonological production.

Results demonstrated that picture naming elicited fewer nonword errors than reading and repetition and that the phonological accuracy observed within nonwords was lower in naming than in reading and repetition. The phonological frequency distributions within nonwords conformed to the typical frequency distribution of English, suggesting that the residual phonological network in Jargon aphasia conforms to the statistical properties of the typical, learned system and that nonwords are constrained by lexical processing mechanisms. These results do not completely align with either of the hypotheses outlined above, but can be best explained by a phonological impairment, since tasks which increase focus on phonological material lead to an exacerbation of Jargon behaviour. However, lower phonological accuracy was observed in naming (see Figure 3.2, Appendix 8.10), suggesting a contribution of inaccurate lexical/semantic information to Jargon production. An additional semantic level of impairment would account for this error profile, in that semantically related words are very rarely phonologically related, therefore, if semantic impairments are contributing to inaccuracy/noise in lexical retrieval, the distortion of resulting nonwords will be greater.

The phonological accuracy analysis at the case-series level (see Figure 3.3) demonstrated that the majority of nonwords contained above chance accuracy, indicating that lexical access had taken place and that nonwords were generated with reference to target phonological information, supporting the phonological hypothesis. The case-series analyses of nonword phonological accuracy distributions (see section 3.4.2.2) further support the phonological hypothesis in that nonword accuracy aligned, largely, to a continuous distribution, suggesting a single source of error generation. Three of the ten participants (p4, p9 and p10) demonstrated significant skews in their accuracy distributions, which reflected high proportions of nonwords with low accuracy phonological content, mostly in picture naming. These patterns, taken alongside the above chance accuracy (apart from p4), suggest significant phonological processing impairment underpins nonword production for these participants. Taken together, results from Chapter 3 suggest that nonword production in Jargon aphasia is most associated with phonological processing impairment and that increasing focus on phonological material, such as phonemes presented as part of auditory repetition, bias the word production network to utilise this information which increases the chance of Jargon production.

6.2.2 Comparing Jargon production across different tasks

In aphasia, people tend to be more accurate in word production tasks which include surface level word information (e.g. reading and repetition) in comparison to naming because they can use the phonological/graphemic information provided in repetition and reading to support phonological encoding (Nozari & Dell, 2013; Nozari et al., 2010). This pattern is often taken as evidence for dual route frameworks of repetition and reading, demonstrating that additional nonlexical information boosts phonological selection and indicates that tasks of repetition, reading and naming are associated with different lexical-phonological demands. A number of recent studies focused on Jargon aphasia have capitalised on this inherent task difference and used these production tasks to explore how phonological aphasia manifests across them, with a view to informing on the underlying nature of the impairment.

Results from Chapter 3 demonstrate that, in Jargon aphasia, tasks which are associated with additional nonlexical processes, such as repetition and reading, elicit higher numbers of nonword errors and exacerbate Jargon production. Similar trends have been reported in other Jargon case studies. For example, in Olson et al. (2015), participant VS produced greater numbers of nonword error in repetition in comparison to naming and reading and participant JH was most errorful in reading, aligning with the pattern observed in Chapter 3 which indicated that tasks which increase phonological processing demands increase the severity of the production impairment. However, this pattern does not always emerge in all persons with Jargon aphasia, as in the same study, participant JW produced similar error numbers across tasks; although naming was the most error prone. The pattern of error exhibited by JW suggests that, for some people with Jargon, lexical-semantic processes are contributing to the error profile. Moses et al. (2004) also report a discrepancy between error numbers across these three production tasks, with participant KVH producing fewest errors in repetition and significantly more in reading and naming. Many of the larger scale cross-task comparison studies consider nonword error mechanisms within fluent aphasia more broadly and often focus on picture naming (Schwartz et al., 2004) or analyse error quantity but not quality (Nozari et al., 2010), which makes integration of the current patterns in relation to the broader literature challenging. These larger studies of fluent and nonword production in aphasia include few people who fit the Jargon aphasia criteria, in that most participants do not produce nonwords as their main error response. In Nozari et al., (2010) there are three Wernicke's participants and two Conduction participants who fit this criteria; these participants produce similar numbers of nonword errors across repetition and reading (see Table 1, Nozari et al., 2010), suggesting that the production profile of these participants does not completely align with that reported in Chapter 3. Taking the broader literature into consideration, there is evidence to suggest a lexical-semantic contribution to Jargon production in some cases; however the major pattern suggests a predominantly phonological impairment.

This pattern can be explored with greater specificity by considering the neurological data of the Participants in Chapter 3. Many case-series studies lack the necessary experimental power to statistically explore neural correlates of Jargon production and instead often provide a qualitative interpretation of the lesion correlates in individual participants. Considering studies of Jargon aphasia which take this approach, high lesion overlap in Superior and Middle Temporal Gyri, the Temporo-Parietal junction and inferior parietal regions (Dell et al., 2013; Kertesz & Benson, 1970; Pilkington et al., 2017) is often identified. These regions are associated with semantic analysis, lexical access and phonological processing and retrieval for production (Baldo, Katseff & Dronkers, 2011; Binder, 2017; Indefrey, 2011; Indefrey & Levelt, 2004; Roelofs, 2014). Using the Harvard – Oxford Cortical – Subcortical atlas via MRIcron (Rorden & Brett, 2000), lesion profiles for the participants presented in Chapter 3 were generated. One lesion overlay included participants who produced exceptional patterns of production (p4, p9, p10) in that their naming accuracy was close to (p9 and p10) or at chance (p4). The second lesion overlay included the remaining six participants whose production patterns aligned more closely with the phonological hypothesis (see Figure 6.1), in that they were clearly above chance accuracy in all three production tasks. The resulting two lesion overlays were inspected for regions of high overlap and contrasted with one another to identify similarities or differences in the lesion profiles. This analysis demonstrated that lesion patterns across the whole group were similar, commonly involving the planum temporale, the superior and posterior middle temporal gyrus. This pattern aligns with the phonological hypothesis, in that these regions are associated with phonological analysis of the speech stream, the translation of auditory-sensory into motor information and the retrieval of phonological code during word production (Buchsbaum et al., 2001; Hickok, Buchsbaum, Humphries, & Muftuler, 2003; Levelt, 2001; Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1996). The three participants who produced more severely impaired naming performance (p4, p9 and p10) presented with additional damage to the anterior supramarginal gyrus and the parietal and central opercular regions (see A & B). This extended lesion profile has been associated with word naming processes (Edwards et al., 2010) and undifferentiated Jargon (Hojo, Watanabe, Tasaki, Sato, & Metoki, 1985), a sub-type associated with more severe nonword production than typically observed in neologistic Jargon. This pattern suggests that additional lexical selection impairments may underpin more severe Jargon production; however, further lesion analyses are required, across larger groups of people with Jargon aphasia, to evaluate this.

A

B

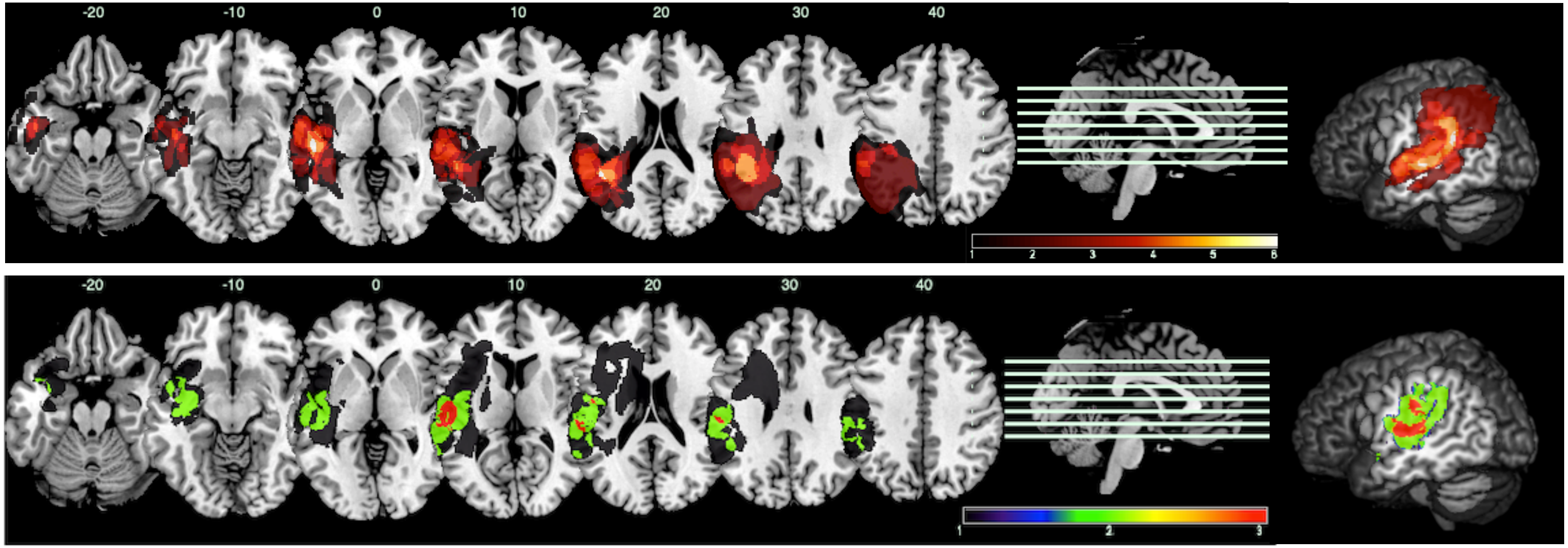


Figure 6.1: Lesion overlays for participants who produced normal phonological accuracy distributions (A) and participants who produced non-normal phonological accuracy distributions associated with low accuracy naming production (B).

6.2.3 Chapter 4: Intrinsic manipulation

Building on Chapter 3 results, which demonstrated that phonological processing impairment is integral to Jargon aphasia, Chapter 4 explored whether phonological processing success in Jargon aphasia was influenced by the ease and availability of information provided to the phonological system from lexical processes. Target word sets characterised by high or low lexical availability (see Appendices 8.6 & 8.7) were used in tasks of single word reading and repetition to test this. Jargon production was measured by nonword quantity and quality; the latter indexed by phonological accuracy and phoneme preservation. Ten people with aphasia and Jargon-like production were included in this study and group and case-series analyses were implemented. It was expected that Jargon would be less severe when processing words which have greater lexical availability, in comparison to words with lower lexical availability. This hypothesis, based on lexical effect patterns reported in larger groups of people with aphasia (e.g. Nozari et al., 2010), was derived from evidence in simulated word production frameworks which indicate that highly available words reside with greater activation which allows or more successful activation transfer and more accurate phonological selection during word production. Words with less activation (e.g. lower frequency or imageability words) are associated with weaker activation patterns which can be more easily affected by impairments in word and phonological selection. It was also expected that word reading would elicit stronger lexical effects than auditory repetition. This is because comprehension and lexical processing of written material is more preserved than comprehension and lexical processing of spoken material in Jargon aphasia. Because of these differences in lexical comprehension, it was expected that word reading, where target words are more likely to be recognised and understood, would elicit greater lexical processing patterns. Word repetition, which is associated with poorer comprehension, would likely weigh less heavily on lexical processes and increase reliance on nonlexical processing.

Group results indicated that fewer nonwords were produced when lexical availability was lower, supporting the main hypothesis that Jargon production would be less severe when lexical availability was greater. This indicates that production and phonological processing in Jargon aphasia benefit from increased lexical availability in that fewer nonwords occur and aligns with evidence presented in Chapter 3 which demonstrated that fewer nonwords occur in production tasks where lexical-semantics are most engaged. However, group analyses of phonological accuracy and perseveration within nonwords demonstrated no difference in nonword quality across the lexical availability conditions, which challenges this interpretation and suggests that lexical availability has a binary effect on phonological production in Jargon aphasia. This binary effect is characterised by a reduced quantity of nonwords; however nonword severity, in terms of phonological accuracy and perseveration, does not alter under the lexical availability conditions. This suggests the qualitative nature of the errors is not influenced by lexical-semantic availability. The case-series analyses identified a subset of 4 participants who demonstrated more consistent, non-binary, lexical effects in auditory repetition; three of these participants (participants C, D and E) presented with moderate levels of Jargon production (see Figure 4.6 & Figure 4.8). Participants who presented with either mild or severe nonword production patterns showed little or no lexical effects in nonword quality, suggesting that their phonological production was not consistently influenced by lexical-semantic processes. The severity of Jargon production, ordered by the quantity of nonword errors produced, was associated with phonological processing impairment, indicating that the degree of Jargon and phonological processing ability dictate whether lexical effects in production will occur. This suggests that a moderately impaired phonological system benefits from greater engagement of lexical-semantic processing. It was also expected that lexical effects would be enhanced in reading aloud, since access to lexical information is more preserved via the written input versus auditory input in Jargon aphasia. However, the opposite was observed, and only auditory repetition elicited the hypothesised lexical effects. It is interpreted that lexical effects are observed in repetition more so than reading because the static nature of stimulus presentation in reading aloud encourages focus on nonlexical surface word material and reduces the weight on lexical processing.

6.2.4 Lexical effects in Jargon aphasia

There is inconsistent evidence of lexical effects in Jargon and phonological forms of aphasia (Wilshire & McCarthy, 1996). This is contrary to the pattern observed in healthy speakers and the larger aphasia population where word production is consistently demonstrated as more efficient and accurate for words which are more frequent and familiar (Coltheart, Rastle, Perry, Langdon & Zeigler, 2001; Hanley & Kay, 1997; McCarthy & Warrington, 1984; Nozari et al., 2010). In some cases of phonological aphasia lexical effects are enhanced (Jefferies et al., 2006; Martin & Saffran, 1997), as demonstrated by Jefferies et al. (2006) in their case-series report comparing lexical effects (manipulated uisng frequency and imagability) in people with semantic and people with phonological forms of aphasia. The phonological group showed strong effects of lexicality (including imagability) in immediate and delayed repetition with effects enahced in the latter, whereas people with semantic impairments showed little or no lexical effects in their production patterns. In addition, there was a negative relationship between the degree of phonological processing capacity and the imagability effects. Jefferies et al. (2006) suggested that delayed repetition increases the weight on phonological processing which increases the difficulty for people with phonological impairment and encourages increased reliance on lexical-semantic represenations which results in greater lexical effects. This suggests that lexical-semantic effects should increase in line with phonological processing impairment. However, this was not the case in the Chapter 4, as only people with moderate Jargon aphasia exhibited consistent lexical effects. On further examination of the participants included within Jefferies et al. (2006), the phonologically impaired participants present with moderate to severe phonological impairments as indicated by their performance on phonological tasks (e.g. phoneme segmentation, see Table 3 in Jefferies et al., 2006). However, the production profiiles of the participants reported in Jefferies et al. (2006) do not indicate Jargon aphasia, as spoken picture naming accuracy was 50% or above for all participants. Furthermore, the participants within Jefferies et al. (2006) are described as producing semantic errors in repetition which is a production pattern rarely observed in Jargon aphasia and not associated with phonological forms of the impairment, where people produce nonword or phonological errors almost exclusively (see Table 5.3 and Appendix 8). Therefore, whilst the phonological input processing of Jefferies et al. (2006) particpants were similar to that obserbed in Jargon aphasia, the phonological output capabilities appear more preserved. This highlights the subtle yet important distinction between phonological input and output processing which is not fully understood from either the behavioural or the neural perspective (Buchsbaum et al., 2001; Damasio, 1992; Martin & Saffran, 2002; Roelofs, 2014). A small number of existing studies exploring Jargon-like and phonological aphasia align with results in Chapter 4, reporting a lack of lexical effects in production (Ackerman & Ellis, 2010;

Corbett et al., 2008; Gotts et al., 2002). Overall, the evidence for lexical effects in people with phonological output difficulties is weak, which implies that the emergence of lexical effects in production is heavily dependent upon the functioning of the phonological output system.

Martin and Saffran (2002) attempt to disentangle phonological input and output processes, suggesting that measures of phoneme discrimination and rhyme judgement (which were used in the current thesis to profile phonological ability) index the integrity of mapping between acoustic input to phonological nodes, whereas the number of target related non-word errors produced in single word production are the most reliable indicators of phonological output impairment. They demonstrated that, in a group of 24 people with aphasia, performance on these metrics was closely associated, suggesting either a common phonological system or a close association between phonological input and output systems. Martin and Saffran (2002) further examined this pattern using the number of false alarm errors – erroneously identifying a nonword as a real word – made on a task of auditory lexical decision. This metric was selected based on evidence suggesting that this task supports identification of a phonological impairment separate to that identified by phoneme discrimination, as indicated by case-study patterns showing little or no impairment in phoneme discrimination but significantly impaired lexical decision performance (Allport, 1984; Martin, Breedin, & Damien, 1999). Martin and Saffran (2002) found that the number of false alarms aligned closely with performance in phoneme discrimination and the number of phonological nonwords produced in naming, further suggesting a common phonological process or close overlap in input/output phonological processes. However, there was a specific case, EF, who performed well on phonological input tasks of phoneme discrimination but produced a disproportionally high number of nonword errors in naming, suggesting a specific phonological output impairment. Whilst EF performed with relative success on the lexical decision task, she produced a number of false alarm errors, indicating a relationship between the number of errors made on auditory lexical decision tasks and phonological output processing. An earlier study by Miceli, Gainotti, Caltagrione and Masullo (1980) also found discrepancies between performance on phonological input (phoneme discrimination tasks) and output abilities (phoneme errors in output) in aphasia. This suggests that separate impairments in phonological input and output can present in single cases and indicates that separate, independent systems for input phonological processing (decoding) and output phonological processing (encoding) exist. It is possible that separating these systems in stroke patients is difficult because of the proximity of neural regions associated with these processes, which make it unlikely that one system would be damaged whilst the other is spared.

Results from Chapter 4 indicated that lexical effects emerge in people with moderate Jargon production, which was indexed by the quantity of nonword errors produced and was associated with moderately impaired phonological input processing. Whilst the input abilities of participants reported in Chapter 4 aligned with those reported in other cases of aphasia where lexical effects in production emerged, the output abilities of the Jargon participants were substantially more impaired. This, taken alongside the evidence that phonological output and input processes can be independently functioning and impaired, supports the interpretation that the lack of lexical effects in Jargon is dictated by the degree of phonological output processing. A lesion overlay analysis was conducted, similar to that presented in Figure 6.1, to compare the lesion profiles of participants who did and did not display consistent lexical effects (see Figure 6.2) to explore the underlying neural correlates associated with lexical effect status in Jargon aphasia and to determine whether differential damage to phonological networks was evident between those who did and did not display lexical effects. The lesion profiles did not reveal any significant differences between the two sub-groups of participants, with areas of lesion overlap encompassing posterior portions of the middle and superior temporal gyrus and the inferior parietal regions in both groups – highly similar to the lesion profiles of the participants presented in Chapter 3 (see Figure 6.1). Lesion data were unavailable for two participants presented in Chapter 4 meaning the current data and corresponding lesion overlap regions are not fully representative of the behavioural patterns reported in Chapter 4. This meant that there was insufficient data to enable lesion analysis across the three-subgroups of participants displaying mild, moderate and severe Jargon production, which would have optimally informed the current research question.

A

B

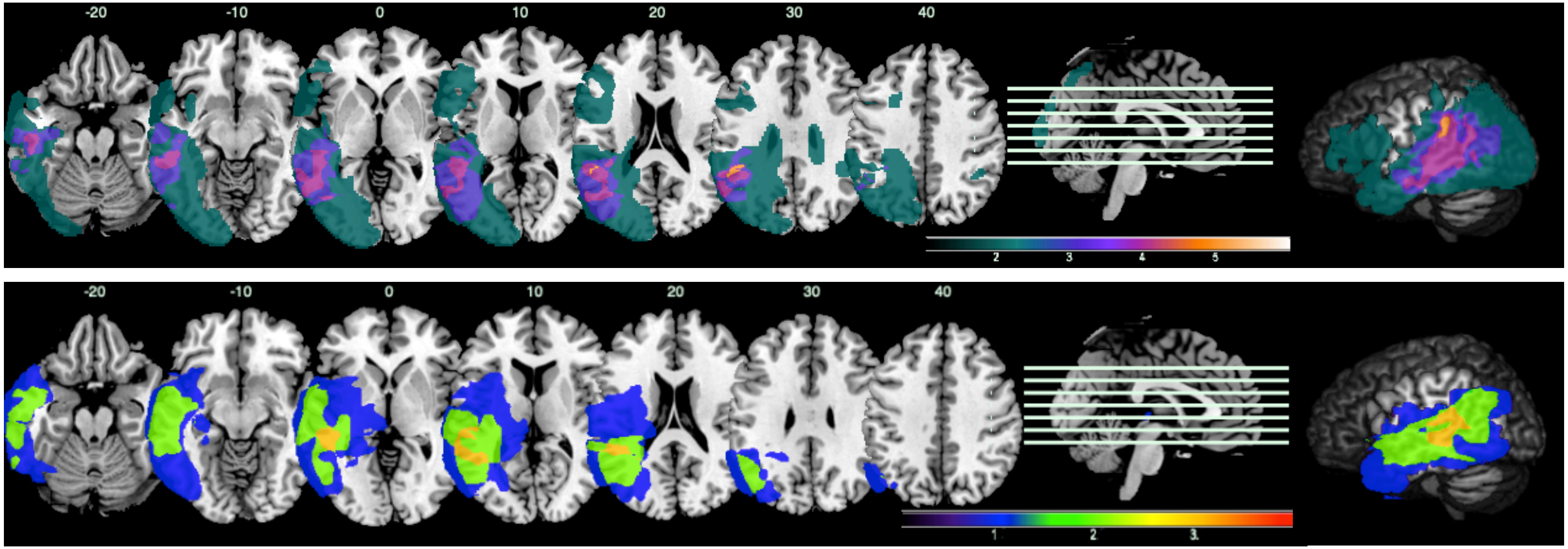


Figure 6.2: Lesion overlays for participants who demonstrated no lexical effects in production (A) and participants who demonstrated lexical effects (B)

6.2.5 Chapter 5: Extrinsic manipulation

This chapter examined whether inhibitory processing could be manipulated to create a more optimum environment for phonological encoding in Jargon aphasia. To target inhibition, the length of time allocated between single word items within a list for production was manipulated and non-language material was presented in between target words in a single word reading aloud paradigm. These manipulations were implemented to probe the window after word production – when phonological segments should be turning off after use (Fischer-Baum & Rapp, 2012). Overall, there were four different experimental conditions in which the reading aloud task was completed. Three of the conditions, referred to as trial types, added seven seconds in between each target word, with a static fixation cross (Pause trial), a pattern-reversing checkboard (Passive trial) and a visual discrimination task (Active trial) presented during the inter-stimulus interval. There was also a Standard delivery reading task, where the target words were read aloud consecutively with no additional inter-stimulus time or task. Eight people with Jargon aphasia are included in this study and both group and case-series analyses were implemented to evaluate whether nonword quantity, phonological accuracy and phoneme perseveration changed under the different word production conditions.

Results showed that, at the group level, Jargon behaviour was not different across the trial formats; however, the case-series analyses identified that five from the eight participants showed effects of the trial formats in their production patterns. Within this subset of participants, the passive stimulation (pattern-reversing checkerboard) was the most effective in eliciting improved accuracy and less perseveration, suggesting that material which generates automatic attention switching presented after response completion is the most effective way of facilitating phonological inhibition. The group data suggest an overall trend in this direction, though this result did not reach statistical significance (see Figure 5.6). Trail making tasks were used to quantify switching ability – the capacity to change tasks – in all participants. Performance on the trail making tasks was interpreted in relation to the trial format effects observed across participants, which require participants to task switch under different conditions to determine whether success in switching tasks in word production trial formats aligned with the ability to task switch in trail making.

This analysis suggested that participants who displayed preserved switching ability on the trail making tasks were unlikely to benefit from the inter-stimulus time/task manipulations. This implies that that individuals with more preserved switching ability do not have an inhibitory or switching component to their Jargon production, in that they were able to switch successfully, and production was unaffected when more time was allowed for inhibitory processing to complete. Participants whose production was affected by switching demands, i.e. improved production or less perseveration when different material was presented, were more likely to demonstrate poorer performance in the trail making tasks. This indicates that these individuals present with impaired ability to task switch, but that when a task switch was enforced with the use of interstimulus manipulations, this facilitated phonological inhibition. This suggests that there is an inhibitory or switching component to the phonological production patterns for some people with Jargon aphasia.

6.2.6 Inhibitory factors in Jargon aphasia and perseveration

Early accounts of Jargon aphasia and perseveration postulate issues with inhibitory processing as causal, based on the copious and highly errorful spoken production (Hudson, 1968; Papagno & Basso, 1996; Sandson & Albert, 1984). However, many of these accounts lack robust experimental evaluation of this theory. Dell et al., (1997) tested both the impact of altered decay rates on word production errors and the influence of poor activation between lexical network layers, comparing their model performance against production patterns from 21 people with fluent aphasia. When Dell et al., (1997) manipulated the duration of activation after selection and processing (simulating inhibitory processing, when units turn off after selection), real-word errors were more likely (semantic, mixed, or formal). In addition, the likelihood of observing a nonword increased as the strength of activation prior to selection was reduced (simulating weakened activatory processing). This suggests that altered inhibitory rates are not a significant factor in nonword production. Case studies which report on individuals with Jargon aphasia document patterns that conform to this finding, demonstrating that perseverative errors tend to occur in close temporal proximity to their target and that there exists a linear relationship between the numbers of perseverative and non-perseverative errors, suggesting the two errors arise from one underlying mechanism or source (Cohen & Dehaene, 1998; Hirsh, 1998; Martin & Dell, 2007). Reduced or failed inhibition predicts largely perseverative errors, which arise when previous activation patterns cannot be efficiently turned off or inhibited. This pattern would not predict non-perseveration error. Deficient activation of the target word, which allows non-target phonology to compete and intrude with the current target can allow for both perseverative and non-perseverative errors, with sources of competition arising from intrinsic noise and residual activation of previously selected units. Therefore, similar quantities of perseverative and non-perseverative errors are best explained by the deficient activation account rather than the faulty inhibition theory.

However, a number of case reports demonstrate error patterns that are inconsistent with the activation account and suggest that inhibition failure may be contributing to the error profile for some people with Jargon-like aphasia. For example, Cohen and Dehaene (1998) and Hirsh (1998) observed long distance, above chance perseverations. This cannot be explained by residual activation overriding inefficient target activation as this would typically affect responses at a lag of one to three subsequent trials, as demonstrated by priming studies. Fischer-Baum and Rapp (2012) demonstrated that, whilst the activation hypothesis accounted for most of the grapheme selection errors observed in by their participant group, reflected by the relationship between perseverative and non-perseverative grapheme errors, one participant produced predominantly perseverative grapheme errors alongside very few non-perseverative errors, which is more consistent with an inhibitory deficit. To identify whether such a pattern was present in the current group of individuals a correlation analysis was used to examine the relationship between the number of perseverative and non-perseverative phoneme errors that occurred from the previous production across the eight participants included in this chapter. The number of perseverated and non-perseverated phoneme errors were counted from each of the four trial types and the total number of perseverated phoneme errors were summed, as were the total number of non-perseverated phoneme errors. The correlation analysis identified that there was no significant linear relationship between the number of perseverated and non-perseverated phoneme errors in word reading (r = .619, p = .102); however, on data inspection, Participants 4 (dark green) and 5 (turquoise blue) deviated from the line of best fit (see Figure 6.3). This indicates that participant 4 produced a disproportionately high number of non-perseverated phonemes and that participant 5 produced a disproportionately high number of perseverated phonemes. The pattern displayed by Participant 5 suggests that inhibitory processes may be contributing more significantly to his phonological production than activatory processes, whereas the opposite appears to be true for Participant 4. The error patterns produced by the remaining six participants appear to demonstrate a more linear relationship between the number of perseverated and non-perseverated phoneme errors, conforming to the pattern expected by the deficient activation account. This demonstrates that neither the inhibitory or activatory accounts of phoneme error and perseveration can comprehensively account for all patterns observed in current group of participants and that a combination of deficits affecting both processes to differing degrees is likely to underpin perseverative and non-perseverative patterns of error in Jargon aphasia.

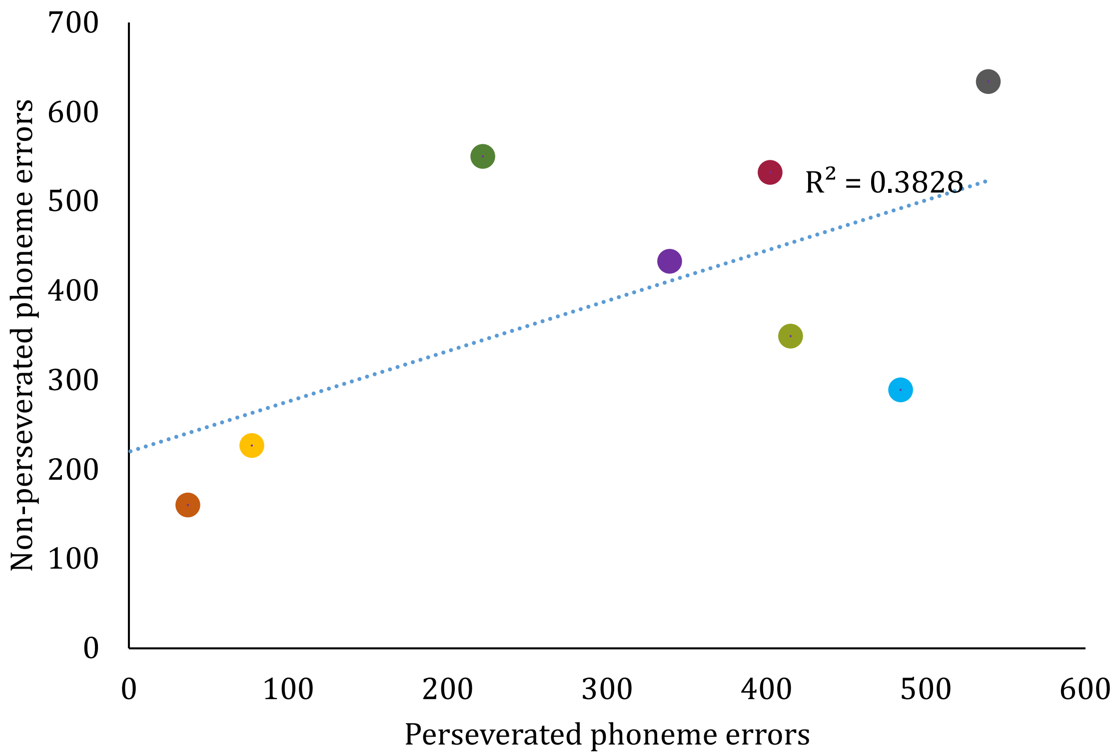


Figure 6.3: Perseverated and non-perseverated phoneme errors produced on single word reading aloud across all four trial types.

In addition to demonstrating that inhibitory processes contribute to Jargon production, Chapter 5 also attempted to manipulate the success of inhibitory processing in order to identify conditions that are optimal for phonological encoding. Experimental attempts to manipulate and target inhibition often use priming paradigms such as semantic blocking – naming a list of semantically related items consecutively then switching to naming a different set of semantically related items. In a semantic blocking paradigm activation spreads across competitors/relations, incrementally increasing with the presentation of each semantically related item and accumulating competing activation, making it increasingly difficult to outcompete neighbouring representations and select the target. Behavioural patterns in healthy speakers and people with nonfluent aphasia align with this explanation, demonstrated by increased response latency and more errorful production in semantically blocked versus unblocked conditions (Schnur et al., 2006; 2009; Damian, Vigliocco & Levelt, 2001; Damian, 2003). This semantic blocking effect is not consistently observed in fluent aphasia (Biegler, Crowther & Martin, 2008; Godbold, 2017) and one study focused on fluent aphasia identified that error numbers were *reduced* in a semantically blocked versus unblocked condition (Schnur et al., 2006). This finding aligns with results reported in Chapters 3 and 4 of this thesis, which demonstrated that enhanced lexical-semantic engagement reduces error production and indicates that, for people with phonological aphasia, phonological processing for production is more successful when greater lexical-semantic activation is available for phonological processing. Phonological blocking is where words with a common phoneme onset are presented for consecutive production and is another way in which activatory-inhibitory processing within the language system can be manipulated. Whilst semantic blocking typically reduces the speed and efficacy of related item production, phonological blocking has the opposite effect and enhances the speed and accuracy of related responses (Belke et al., 2015; Schnur et al., 2009). For people with Jargon-like and phonological aphasia, inhibitory (i.e. more errorful) or mixed effects of phonological blocking have been observed (Godbold, 2017; Hodgson et al., 2005), suggesting that targeting phonological activation, specifically, is counter-productive. This aligns with patterns from phonological cuing and therapy in phonological aphasia which demonstrate inconsistent effects of this form of priming (Baum, 1997; Bose et al., 2019; Goldbold, 2017; Robson et al., 1998; Wilshire & Saffran, 2005) and conforms to results from Chapters 3 and 4 which demonstrate increased error production in response to tasks which increase weight on phonological processing.

Neural associations of the phonological priming effect localise to superior temporal regions and suggest that positive priming effects are underpinned by enhanced retrieval of phonological codes (Biegler et al., 2008; De Zubicaray et al., 2002; Piai & Knight, 2017). The lesion and cognitive profile associated with Jargon aphasia indicates damage to these neural/cognitive functions, and therefore, it is unsurprising that people with Jargon and phonological aphasia demonstrate increasingly errorful production as phonological demands are maximised. Unpublished thesis work by Godbold (2017) examined phonological blocking effects in six people with Jargon aphasia, demonstrating that reverse phonological priming effects (i.e. more errors within a phonologically blocked task) were observed for the people with more severe Jargon aphasia, whereas those with milder Jargon produced either no effects or positive effects, conforming to patterns demonstrated by controls. This dissociation suggests that the phonological priming effect is dependent on the severity of phonological processing impairment, and further supports conclusions in Chapter 4 which suggests that the ability to modulate the functioning of phonological processing is dependent on the functioning of the phonological system. According to the results reported in Godbold (2017), increasing the amount of phonological activation by use of phonological blocking increases perseveration for those with more severe Jargon, suggesting that the inhibitory processing abilities of these participants is insufficient to overcome the phonological reinforcement created by the paradigm. This indicates that issues with inhibitory processing contribute to the production patterns demonstrated by people with more severe Jargon and aligns with the overall pattern reported in Chapter 5, where participants 5, 6, and 8, who presented with more severe Jargon, demonstrated effects of the trial manipulations (targeting inhibitory processing) on their perseveration patterns (see Figure 5.7).

This interpretation is also supported by results in Chapter 4, which identified reverse frequency effects, that is more severe perseveration when processing higher availability words, in participants G and H (participants 5 and 6 in Chapter 5). In Chapter 4, words with greater lexical availability were expected to elicit less perseveration because the stronger activation patterns associated with highly available words should more successfully override competition from residual activation. However, it is possible that, for people who present with inhibitory deficits, the stronger patterns of activation associated with higher frequency and imageability words would maximise inhibitory demands and make perseveration more likely. Patterns of inhibitory processing impairment are observed for participants G/5 and H/6 across Chapters 4 and 5, strengthening the interpretation that inhibitory deficits are contributing to their Jargon profiles and identifying a contribution from impaired inhibitory processing for some individuals with Jargon aphasia.

6.2.7 How do these results conform to the theories of Jargon?

Nonwords and phonological errors in Jargon aphasia are hypothesised to arise from a phonological source of error or from additional or alternate lexical retrieval mechanism associated with failed access to the word form. In the latter, phonological production is based on surrogate phonological construction and not on the target word representation, whereas in the former, phonological production is based upon the target word representation. The mechanisms associated with these theoretical positions posit weakly activated and/or poorly inhibited lexical-phonological representations as causal. Results from the current thesis indicate that phonological processing breakdown in integral to the Jargon aphasia presentation. Chapter 3 identified that phonological content of nonwords was consistently above chance (see Chapter 3), indicating that nonwords reflect the correctly identified target word which has been disrupted during phonological processing, and that Jargon production was increasingly impaired when focus on phonological material was increased. Chapter 4 results also provide support for the phonological hypothesis, as the majority of the group failed to exhibit consistent lexical effects and the pattern of lexical effects observed across the group was dependent on the functioning of the phonological system, suggesting that Jargon production patterns are dictated by phonological processing ability.

Conduction theory, one of the major accounts associated with phonological error in Jargon aphasia (see Chapter 1), suggests that the correctly identified target word is disrupted during further phonological processing, sometimes attributed to a post-lexical phonological process. The lexical-phonological account, which implicates partial activation of the target phonological representation during lexical processing, also suggests that Jargon aphasia is a manifestation of phonological selection impairment; however, this theoretical position places the phonological breakdown within the lexical system. Lexical effects are associated with this theoretical account in that stronger patterns of activation are associated with higher frequency and more imageable words, which means that transfer of activation to target phonology is more likely to be successful. This thesis has not explicitly considered whether the phonological breakdown in Jargon occurs as a part of or extrinsic to lexical selection; however, interpretation of production patterns exhibited by certain individuals provide some evidence to support both of these positions.

Chapter 4 demonstrated a group effect of lexical availability, showing that fewer nonwords were produced when lexical activation was greater. This suggests that the phonological processing is influenced by lexical activation patterns and aligns with data presented in a number of existing studies of nonword production which interpret this as evidence for a phonological selection mechanism which is part of lexical access (Dell et al. 1997; Nozari et al., 2010; Olson et al., 20015). For four participants, these lexical effects were more consistent and impacted on the phonological quality of their production; however, the majority of the group demonstrated phonological quality patterns that were resistant to the lexical manipulation. Explaining the lack of lexical effects in the quality (POI and perseveration) but not the quantity (number of nonwords) analyses is not straightforward. One possibility is that there was insufficient experimental power to demonstrate this effect at the group level. The distributions of phonological accuracy (see Figure 4.5) in repetition suggest that there was a trend in the hypothesised direction, implying that there was increased phonological accuracy in the highly available word set, but it was insufficient to reach statistical significance. However, the same number of participants were entered into both the quantity and quality analyses, therefore, this interpretation does not fully account for lexical effects observed in one analysis but not the other. An alternative interpretation is that the balance between lexical and nonlexical processing meant that this effect was over-ridden because nonlexical processing was utilised over lexical processing because impaired lexical comprehension meant that the use of this processing route is less likely (Nozari & Dell, 2013). However, this pattern does not clearly emerge, because lexical effect status was not dependent on lexical-comprehension ability, but rather, depended upon phonological processing ability. This suggests that a phonological output mechanism dictates whether these effects emerge, which is more consistent with a post-lexical impairment that distorts a retrieved string (Goldrick & Rapp, 2007).

This pattern could be explained by a severe impairment in phonological processing which distorts all inputted strings to similar degrees. An alternative interpretation is that there could be lexical activation issues in addition to post-lexical phonological impairments with errors arising at both processing levels. The latter would more completely explain the consistent and low access to target phonology demonstrated in Chapter 3 (see Figure 3.3 and Figure 3.4) in that a solely post-lexical impairment would more likely distribute errors with a wider range of severity. The current results provide little support for a complete failure in lexical access, as nonword content is consistently above the chance estimate (see Chapter 3). Taken together, the current results reveal the spectrum of phonological and nonword production impairment associated with Jargon aphasia. This spectrum can be best explained by a combination of impairments associated with these theoretical perspectives, with phonological/conduction deficits common to all, as demonstrated by the above-chance phonological production and exacerbated error profiles on phonological tasks which weigh heavily on phonological processing and less heavily on lexical-semantic processing. Additional, lexical factors also contribute to the Jargon presentation in some individuals, indicated by the lexical effect pattern observed in Chapter 4; however, the emergence of these effects depends largely on the functioning of the phonological system.

6.3 ***Methodological approaches***

6.3.1 Case-series design

Across Chapters 3, 4, and 5, group-level results generally identified little or no effects of the experimental manipulations; however, the case-series results provided rich information on the nature of the experimental effects and informed the interpretations and conclusions of this thesis. This dissociation between the outcomes of the group-level and case-series level analyses demonstrate the importance of implementing a case-series design in studies of aphasia. The case-series approach applies the same analysis to each individual participant and the effects observed in each participant are considered individually and in relation to the rest of the group. In the current thesis, the experimental effects observed across participants were considered in relation to additional impairment information, such as semantic processing ability (see Chapter 4) or switching capacity (see Chapter 5), to provide information on the cause and associations of the experimental effects and to understand why effects are absent in certain individuals. Omission of the case-series analyses and adoption of a group-only design would have yielded significantly different conclusions. For example, the group-level results from Chapter 4 identified no lexical effects in phonological accuracy and perseveration, whilst group results from Chapter 5 demonstrated no effects of the inter-stimulus manipulations over production performance. The case-series results identified lexical effects in 4 participants (Chapter 4) and effects of trial formats in 5 participants (Chapter 5), which were overridden in group analyses because effects in opposite directions were also present. Only when participant data was analysed independently, and results integrated across the group did it become clear that lexical effect status was dependent on phonological processing capacity or that that inter-stimulus manipulation facilitated improved production for half of the group in Chapter 5. This illustrates the advantage of the case-series design in aphasia populations, which are typically heterogeneous in nature, and explains why a high number of studies adopt this design (Dell & Schwartz, 2011; Fischer-Baum, 2013; Rapp, 2011).

One of the challenges when adopting a case-series approach is the large amount of data that requires processing and the amount of information which contributes to the overall conclusions and interpretation of the research. Schwartz and Dell (2010) suggest that a sufficiently large sample size is essential to disentangle effects, whilst Nickels, Howard and Best (2011) argue that the presence of a single outlier within a group is sufficient to falsify a theory, implying that large participant numbers are not essential to explore theoretical hypotheses associated with clinical cases. However, a large participant *N* in clinical aphasia studies is often difficult to achieve, meaning much of the literature focusing on relatively rare clinical presentations, such as Jargon aphasia, reports on cases of two or three individuals (see section 2.3 Recruitment challenges). The experimental chapters included in the current thesis focus on a maximum of ten participants at a time, which despite being one of the largest reports on Jargon aphasia, is comparatively small next to studies considering aphasia or fluent aphasia more broadly (Dell et al., 1997; Martin & Dell, 2007; Schwartz et al., 2004). Yet, despite the relatively small participant numbers in each chapter, substantial variation was observed, meaning detailed consideration of cases was required to support interpretation. One alternative to the current approach would be to report single case studies in greater depth for each participant. Single case studies are a common feature of the Jargon aphasia literature, and whilst they provide comprehensive profiling of specific and interesting cases, they do not place the observed patterns in the context of a wider group of participants, meaning it is unclear whether patterns observed in one participant are upheld and explanatory for other participants who present a similar impairment. The case-series approach overcomes this issue and provides a more comprehensive account of the disorder being investigated. This allows for more complete understanding of the impairment which in turn allows for better targeted research questions/therapy development which best fits the overall Jargon aphasia presentation.

6.3.2 Measures of behaviour

In this thesis three key features of Jargon behaviour were measured and used as an index of Jargon aphasia production severity. These features were: nonword quantity (the number of non-lexical responses produced); phonological accuracy (the number of target phonological segments produced as a proportion of the target and response lengths); and phoneme perseveration (the number of phonological intrusions from the prior production as a proportion of response length). Nonword quantity is the most widely used measure of the three and in both the current thesis and existing studies, nonword quantity has provided information on the influence of lexical effects and production tasks (Chapters 3, 4, 5; Dell et al., 1997; Nozari & Dell, 2010; Gotts et al., 2002). Whilst this is an important index of Jargon aphasia and used in the current thesis to order people by severity, it does not provide qualitative information on the accuracy within nonwords and thus is limited in the information it can provide about phonological processing disruption. For example, the nonword /lɪvɪdʒ/, produced in response to target word 'village', is more phonologically accurate than the response /kraɪbriː/ which was produced in response to the target word 'tribute'. The phonological accuracy metric distinguishes between these responses, with the former response allocated an accuracy score of 1 (all sound segments were produced) and the latter response allocated an accuracy score of 0.31 or 31% (31% of target sounds were produced). The nonword quantity analysis does not distinguish between these two nonwords, allocating them both as nonwords. For this reason, measures of phonological accuracy are essential to fully profile the severity of phonological encoding disruption in Jargon production. To this end, this thesis implemented the Phonological Overlap Index (POI; Schwartz et al., 2004). This metric has been used in a number of other studies of Jargon aphasia and nonword production impairments (Bose, 2013; Schwartz et al., 2004) and is particularly useful for Jargon-like impairments, where people frequently produce greater amounts of segments than required by the target, because it quantifies the amount of accurate segment production as a proportion of the length of response and target words. The chance of phonologically accurate production increases as the target length increases; therefore, calculating production accuracy with respect to response length partially account for chance, meaning the POI is metric is superior to other phonological metrics which count the quantity of accurate phonemes produced without considering length of response. Measures of phonological accuracy which account for phoneme frequency distribution metrics, for example, the chance of producing a /t/ is significantly greater than the chance of producing an /oi/, would more completely profile phonological production accuracy. Currently, no such single method exists to accomplish this, and the most consistent approach to overcoming this issue is to implement a bootstrapping or permutation procedure as conducted in Chapter 3, comparing observed accuracy against a chance phonological accuracy level (see Chance phonological accuracy).

Perseveration measures are less well established and examining repetitive phonological patterns in a high degree of detail is challenging in a population who produced substantial numbers of phoneme intrusions. This is partly because of the high computational power required to enable such an analysis, but also because statistical concepts and challenges, such as chance perseverations and typical phoneme frequency distributions, all influence phonological production patterns and therefore should be computationally accounted for when quantifying the severity of this behavioural feature. The measures of perseveration adopted in the current thesis are based on existing methods (Godbold, 2017; Martin & Dell, 2007) and account for perseverations observed within the immediately prior response only. Perseveration is not restricted to one prior or one subsequent response and the measure used in this thesis does not capture the full extent of this behavioural phenomenon (Cohen & Dehaene, 1998) and future work examining perseveration patterns should consider the behaviour across multiple preceding trials to fully understanding the nature of perseveration mechanisms in Jargon aphasia. In the current thesis, this measure was used a way of quantifying behavioural severity and to provide information on behavioural change under different experimental conditions, and given that phoneme perseveration is most consistently and strongly observed at a lag of one trial (Ackerman & Ellis, 2007; Corbett et al., 2008), this measure focuses on the temporal duration where most behavioural change should be observed and therefore provides sufficient information relevant for the current research questions. Further research profiling the full extend and severity of perseveration in Jargon aphasia is essential to support the development of more effective management strategies.

Throughout the experimental chapters in the current thesis, implementation of these three measures identified conflicting patterns of performance across and within individuals. For example, in Chapter 4, participant C produced nonword responses that were more phonologically accurate to the highly available target words (see Figure 4.6), but the number of nonwords she produced across the lexical availability conditions were not significantly different (see Table 4.3). Similar dissociations between the behavioural measures of nonword quantity (nonword number) and quality (phonological accuracy and perseveration) were present throughout the analyses for a number of participants, which complicated interpretation throughout. One possibility is that measures targeting quantity and quality are tapping into different underlying processes, and that the occurrence of nonwords versus other forms of response is as a result of a different mechanism to that which operates during the processing of nonwords themselves. This pattern was not analysed as part of the current thesis due to the large proportion of nonword errors observed in the current group of participants. A related analysis was implemented by Olson et al. (2015) who explored response accuracy in Jargon aphasia and asked whether it was observed on a single distribution, suggesting a common source underpinning all error production. The accuracy of all responses (nonwords, errors and correct responses) produced by three Jargon participants did not fall on a single continuous distribution, as would be expected from a single phonological source which is distributing all responses, but rather, correct responses belonged to a separate distribution from other response types, suggesting a separate mechanism governs the production of correct versus error responses. This pattern suggests that separate mechanisms may influence error and other response production and indicates that further work considering broader mechanisms of error in Jargon aphasia is required to fully understand the impairment. For such an approach, a broader group of participants with a wider range of Jargon-like impairments would be required.

6.3.3 Repetition and Reading tasks

Single word repetition and reading can be accomplished lexically, when the word representation within the lexical system is recognised and accessed, and by sub/nonlexical processing where the surface word phonemes/graphemes are processed individually and used to inform phonological processing for production. Picture naming does not involve the presentation of phonological/graphemic information, thus, phonological processing in this task proceeds more directly from conceptual-semantic information. Chapters 4 and 5 of this thesis focused on tasks of repetition and reading which are relatively under-researched in Jargon aphasia, in comparison to picture naming. The major motivation for this choice was to enable maximum experimental control over lexical-semantic variables for Chapter 4, particularly for psycholinguistic variable imageability, which has well documented influence over production efficacy in multiple different paradigms (see section 4.2.2 Lexical influences in reading and repetition). The study design in Chapter 4 required manipulation of lexical-semantic properties (including imageability), such that the psycholinguistic values attributed to word sets significantly differed on these lexical-semantic properties. Implementing such a manipulation in picture naming is impractical because all words that can be clearly represented by an image inherently possess a high imageability value, and therefore, generating target word sets which differ significantly on the imageability property is complex and would limit the precision of the experimental manipulation. Repetition and reading are not constrained by imageability as they do not involve image presentation and therefore allow for greater control over the lexical-semantic manipulation. However, experimental studies focused on repetition and reading often require more complex interpretation because processing can proceed with lexical *and/or* nonlexical/sublexical processing (using the surface word phonemes and graphemes to supplement or base processing on) and the balance between these mechanisms varies across individuals (Nozari & Dell, 2013). One possibility is that people over-rely on surface word information for processing, which, from anecdotal observations during data collection, appeared to be contributing to the behavioural patterns observed in word reading, where the static stimuli encouraged focus on graphemes. It is possible that this influenced both the lack of lexical effects and nonword quality (see Chapter 4) in that, when participants found themselves struggling, they were more likely to reconsider the nonlexical information to supplement the activity in the lexical processing route. Results from Chapter 3 support this interpretation, as greater numbers of errors were observed in repetition and reading in comparison to naming, however the phonological accuracy of responses in the former two tasks was greater. This demonstrates that participants were attempting to use the phonological and graphemic information – albeit with limited success – to enhance production, which in turn led to an increase in the amount of error production. These patterns suggest significant contributions from nonlexical processing pathways in Jargon production and demonstrate that paradigms using repetition and reading as probes of production are particularly useful for this clinical group as these tasks rely on different input processes, with acoustic-phonological perception impaired but visual-graphemic perception preserved. However, the output impairment observed across these two tasks is, for the most part, similar. This implies that the phonological production patterns in Jargon aphasia are driven by a specific phonological output mechanism which similarly distorts production, independent of the clarity of inputted non-lexical information. From this perspective, word reading presents as a promising task for further studying the Jargon aphasia impairment, as input processing in this task is most well preserved.

6.3.4 Clinical implications

The experiments included in this thesis were designed to be clinically relevant and reflect real-world approaches applied in every day speech and language therapy (SLT). Chapter 3 explored the impact of providing phonological and graphemic information to aid word production in comparison to naming words from pictorial information. This reflects an approach commonly used in clinical SLT, whereby written words or spoken phonemic cues are provided to aid access to phonological output representations and facilitate word production. It was expected that people with Jargon aphasia would produce increased nonword errors in picture naming, in line with previous research which suggests that nonword errors occur secondary to word finding deficits, and that there would be fewer nonwords errors in reading and repetition where phonological target word information better guides spoken production. Clinically, this would suggest that therapy which maximises accurate spoken production by utilising multi-modal approaches to word production would be indicated for Jargon aphasia. However, Chapter 3 results demonstrated that the additional graphemic (reading aloud) and phonemic (auditory repetition) had the opposite effect on production, and that people with Jargon aphasia produced more nonword errors when the phonological/graphemic cues were provided. Therefore, contrary to the pattern often observed in aphasia, increasing the amount of phonological information to aid word production leads to an exacerbation of Jargon. This implies that typical phonological and graphemic cuing therapies may be contraindicated for people with Jargon aphasia.

The lexical availability manipulation applied in Chapter 4 reflects a common clinical strategy used to aid correct word production, whereby target words which are more frequent, imageable and familiar are often targeted for therapy as they are easier to access and more resilient to impaired processing. It was hypothesised that people with Jargon aphasia would produce fewer nonword errors as a result of this manipulation and that their nonwords would contain higher proportions of target phonology, on the basis that the denser connection patterns associated with more available words would allow for more successful phonological encoding. This pattern of results would suggest that therapeutic intervention focusing on high frequency, imageable words may lead to reduced nonword production and increased phonological accuracy, which would improve phonological processing and intelligibility if applied in the longer term. However, this pattern only partially emerged, with fewer nonword errors in the highly available word condition but no difference in phonological quality of nonword errors. Therefore, maximising the amount of lexical availability does not consistently impact phonological production for people with Jargon aphasia and this suggests that nonword phonological errors are not benefitting from top-down influences. Chapter 5 design was based on research suggesting that single words processed consecutively are more likely to elicit perseveration if reduced inhibition of phonological segments is associated with Jargon aphasia. It was hypothesised that allocation of greater time or additional non-linguistic tasks would reduce the amount of error and perseveration, suggesting that clinical intervention should target word production tasks interspersed with non-language task or small breaks in between words. However, results did not clearly demonstrate that Jargon production changed as a result of the time and task manipulations, indicating that it is unclear whether perseveration and error in Jargon aphasia are influenced by inhibitory demands. Clinically, this suggests that there is no disadvantage in working with single word tasks and approaches for people with Jargon production and perseveration.

Taken together, the results demonstrate that there was very limited behavioural change in the spoken production of people with Jargon aphasia as a result of the experimental manipulations applied in this thesis. Furthermore, where behavioural change was observed, it was not always in the expected direction (as in Chapter 3, for example), indicating that typical clinical approaches may exacerbate Jargon production. From a clinician's perspective these results are disappointing because they do not suggest a clear strategy or approach for impairment based clinical management for Jargon production. Similar themes are common in the Jargon aphasia literature, where theoretically motivated treatments and management studies generally fail to control or change Jargon production, meaning that clinicians have little research evidence to guide impairment therapy when someone with Jargon aphasia is referred to their caseload. Anecdotally, clinical SLTs report that they often opt for a more functional therapeutic approach, targeting total communication skills with picture boards and gesture; based on the results of this thesis, this approach seems the most logical. However, much of the research to date has approached Jargon aphasia from a linguistic perspective, manipulating semantic or phonological processes in an attempt to manage the production, without considering the role of broader cognitive processes such as attention or motor skill. Further clinical research may be more effective if targeting processes which are relatively unimpaired. For example, people with Jargon aphasia tend to present with relatively spared motor functioning, meaning that motor speech therapy approaches may provide more optimum methods for managing and controlling phonological production in people with Jargon speech.

6.3.5 Future directions

As this thesis has highlighted, phonological processing is key to the Jargon aphasia presentation. However, the disorder is complex and there are numerous, related, language processes which are part of the profile but remain poorly understood. For example, motor and phonetic processes closely interact with phonological processing, however very little consideration has been given to their contribution in Jargon aphasia. A small number of research studies have explored this, using subtle analyses of motor simplification processes to examine whether errors reflect phonetic simplification processes (Godbold, 2017; Olson et al., 2007; Stenneken et al., 2005). These studies find no evidence of motor simplification in Jargon errors suggesting motor-phonetic processes are not significantly contributing to the error profile. However, as identified in Chapters 3 and 4 of this thesis, maximising activation in related but less impaired processes, in this case lexical-semantic processes, can positively influence phonological encoding in Jargon aphasia. Further work evaluating motor contributions in a wider group of people with Jargon aphasia should consider whether motor factors remain relatively spared and whether these processes can be capitalised on to enhance phonological processing and production.

Another process which is closely related to phonological encoding for speech production is phonological perception. Whilst this has not been explicitly tested in the current thesis, further discussion of Chapter 4 results (see section 6.2.4 Lexical effects in Jargon aphasia) suggested a close interaction between input and output processes and, given that the lesion profile of Jargon aphasia implicates both processes, it is likely that both are contributing to production patterns in Jargon. A growing body of research considers the interaction between phonological input and output processing for speech production, focusing on the interaction between perception and production processes online as speech is produced, providing insight into self-monitoring processes associated with speech production. This includes consideration of the neural activation patterns associated with the process, which have been localised to the inferior frontal gyrus, thought to reflect the initiation of motor speech and release of the efference or sensory representation associated with that word, followed by neural activation in superior temporal regions, which reflect speech perception (Chang et al., 2013; Houde & Chang, 2015). Recent methodological developments support the recording of behavioural features associated self-monitoring during spoken production, measuring online speech adaptations, such as vowel centering. Vowel centering describes the online movement and adaptation of formants to ensure the produced vowel adheres to the acoustic and phonetic parameters associated with that specific vowel, such that that specific production falls within the accepted range of articulation. Recording of this behaviour in healthy speakers and people with non-fluent aphasia provides a window into online correction during speech production (Niziolek & Kiran, 2018) and indicates the presence and efficacy of self-monitoring processes. As identified in the literature review, self-monitoring processes have long been considered influential in Jargon production, however few studies present robust evaluation of their contribution. Vowel centering methods may provide a new window into this established but unexplored hypothesis.

6.4 ***Conclusions***

This thesis presents behavioural and neurological data for twenty individuals who have Jargon aphasia. The extent to which different theoretical positions can account for Jargon was considered and manipulations of activatory and inhibitory processing were implemented to explore whether production in Jargon aphasia is associated with impaired lexical or phonological processing and whether phonological production is affected by deficient activation and poor inhibition. Results demonstrate that phonological processing impairment is common across all participants with Jargon aphasia, which conforms to the neurological profile of the disorder which implicates phonological code retrieval processes. However, this thesis also identified the importance of lexical-semantic processing in this disorder which, although impaired in most people with Jargon aphasia, can, in some cases, be maximised to facilitate improved production, suggesting clinical approaches should work to enhance related, more preserved processes that interact with phonological output processing.

Chapter 7. References

Ackerman, T., & Ellis, A. W. (2007). Case study: Where do aphasic perseverations come from? *Aphasiology*, 21(10-11), 1018-1038. doi: 10.1080/02687030701198361

Adlam, A. L., Patterson, K., Bozeat, S., & Hodges, J. R. (2010). The Cambridge Semantic Memory Test Battery: detection of semantic deficits in semantic dementia and Alzheimer's disease. *Neurocase,* 16(3), 193-207. doi: 10.1080/13554790903405693

Alajouanine, T. (1956). Verbal realization in aphasia. *Brain,* 79(1), 1-28.

Alajouanine, T., Sabouraud, O., & De Ribaucourt, B. (1952). The jargon of aphasics; anosognosic disintegration of semantic values of language. *J Psychol Norm Pathol* (Paris), 45(2), 158-180; contd.

Albert, M. L., & Sandson, J. (1986). Perseveration in Aphasia. *Cortex*, 22(1), 103-115.

Allport, A. (1984). Speech production and comprehension: One lexicon or two? In W. Prinz & A. F. Sanders (Eds.), *Cognitive and motor processes* (pp. 209-228). Berlin & Heidelberg: Springer-Verlag.

Baars, B. J., Motley, M. T., & MacKay, D. G. (1975) Output editing for lexical status im artificially elicited slips of the tongue. *Journal of Verbal Learning and Behaviour,* 14, 382-391.

Baldo, J. V., Katseff, S., & Dronkers, N. F. (2011). Brain regions underlying repetition and auditory-verbal short-term memory deficits in aphasia: Evidence from voxel-based lesion symptom mapping. Aphasiology. 26(3-4), 338-354.

Baldo, J. V., Klostermann, E. C., & Dronkers, N. F. (2008). It's either a cook or a baker: patients with conduction aphasia get the gist but lose the trace. *Brain and Language*, 105(2), 134-140. doi: 10.1016/j.bandl.2007.12.007

Balota, D., Yap, M., J., Hutchinson, K. A., Cortese, M. J., Kessler, B., Loftis, B., Neely., J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007). *Behavior Research Methods,* 39(3), 445-459. https://doi.org/10.3758/BF03193014.

Baron, J., & Strawson, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. Journal of Experimental Psychology: *Human Perception and Performance,* 2(3), 386-393. doi: 10.1037/0096-1523.2.3.386

Baron, R., Richard Hanley, J., Dell, G. S., & Kay, J. (2008). Testing single- and dual-route computational models of auditory repetition with new data from six aphasic patients. *Aphasiology,* 22(1), 62-76. doi: 10.1080/02687030600927092

Bastian, H. C. (1869). On the various forms of loss of speech in cerebral disease. *British and Foreign Medical and Chirurgical Review,* 43, 209-236; 470-492.

Baum, S. R. (1997). Phonological, Semantic, and Mediated Priming in Aphasia. *Brain and Language,* 60, 347-359.

Bayles, K. A., Tomoeda, C. K., Kaszniak, A. W., Stern, L. Z., & Eagans, K. K. (1985). Verbal perseveration of dementia patients. *Brain and Language,* 25(1), 102-116.

Belke, E., Meyer, A. S., & Damian, M. F. (2005). Refractory effects in picture naming as assessed in a semantic blocking paradigm. *The Quarterly Journal of Experimental Psychology,* 58(4), 667-692.

Berthier, M. L. (1995). Transcortical sensory aphasia: Dissociation between naming and comprehension. *Aphasiology,* 9(5), 431-451. doi: 10.1080/02687039508248708

Berthier, M. L. (1999). *Transcortical aphasias*. Psychology Press.

Best, W., Herbert, R., Hickin, J., Osborne, F., & Howard, D. (2002). Phonological and orthographic facilitation of word retrieval in aphasia: Immediate and delayed effects. *Aphasiology,* 16, 151–168.

Biegler, K. A., Crowther, J. E., & Martin, R. C. (2008). Consequences of an inhibition deficit for word production and comprehension: evidence from the semantic blocking paradigm. *Cognitive Neuropsychology,* 25(4), 493–527.

Binder, J. R. (2017). Current Controversies on Wernicke's Area and its Role in Language. *Curr Neurol Neurosci Rep,* 17(8), 58. doi: 10.1007/s11910-017-0764-8

Blumstein, S. E., Cooper, W. E., Goodglass, H., Statlender, S., & Gottlieb, J. (1980). Production deficits in aphasia: A voice-onset time analysis. *Brain and Language*, 9(2), 153-170. doi: https://doi.org/10.1016/0093-934X(80)90137-6

Bose, A. (2013). Phonological therapy in jargon aphasia: effects on naming and neologisms. *International Journal of Language & Communication Disorders*, 48(5), 582-595. doi: 10.1111/1460-6984.12038

Bose, A., Höbler, F., & Saddy, D. (2019). Deciphering the mechanisms of phonological therapy in jargon aphasia. *International Journal of Language & Communication Disorders,* 54(1), 123-142.

Bose, A., van Lieshout, P., & Squares, P. A. (2007). Word frequency and bigram frequency effects on linguistic processing and speech motor performance in individuals with aphasia and normal speakers. *Journal of Neurolinguistics,* 20(1), 65-88, doi.org/10.1016/j.jneuroling.2006.05.001

Brown, J. W. (1975). The Problem of Repetition: A Study of "Conduction" Aphasia and the "Isolation" Syndrome. *Cortex,* 11(1), 37-52. doi: https://doi.org/10.1016/S0010-9452(75)80019-0

Brown, J. W. (1981). Chapter 1 - Introduction Jargonaphasia (pp. 1-8): New York:Academic Press.

Brown, J. W. (1981). Chapter 9 – *Case Reports of Semantic Jargon.* BROWN, JASON W Jargonaphasia (pp. 169-176): New York: Academic Press.

Buchsbaum, B. R., Baldo, J., Okada, K., Berman, K. F., Dronkers, N., D'Esposito, M., & Hickok, G. (2011). Conduction aphasia, sensory-motor integration, and phonological short-term memory – An aggregate analysis of lesion and fMRI data. *Brain and Language,* 119(3), 119-128. doi: https://doi.org/10.1016/j.bandl.2010.12.001

Buchsbaum,B. R., Hickok, G., & Humphries, C. (2001). Role of left posterior superior temporal gyrus in phonological processing for speech perception and production. *Cognitive Science,* 25, 663–678. https://doi.org/10.1207/s15516709cog2505_2

Buckingham Jr, H. W. (1981). Chapter 3 - Where Do Neologisms Come From? A2 - BROWN, JASON W Jargonaphasia (pp. 39-62): Academic Press.

Buckingham Jr, H. W., & Kertesz, A. (1974). A linguistic analysis of fluent aphasia. *Brain and Language, 1*(1), 43-61. doi: http://dx.doi.org.idpproxy.reading.ac.uk/10.1016/0093-934X(74)90025-X

Buckingham, H. W. (1977). The Conduction Theory and Neologistic Jargon. *Language and Speech,* Vol 20, Issue 2, pp. 174 – 184. https://doi.org/10.1177/002383097702000209

Buckingham, H. W. (1981). Chapter 3 - Where Do Neologisms Come From? A2 - BROWN, JASON W Jargonaphasia (pp. 39-62), New York: Academic Press.

Buckingham, H. W. (1990). Abstruse neologisms, retrieval deficits and the random generator. *J Neurolinguistics,* 5(2–3), 215-235. doi: http://dx.doi.org/10.1016/0911-6044(90)90012-N

Buckingham, H. W., & Buckingham, S. S. (2011). Is recurrent perseveration a product of deafferented functional systems with otherwise normal post-activation decay rates? *Clin Linguist Phon*, 25(11-12), 1066-1073. doi: 10.3109/02699206.2011.616982

Buckingham, H. W., & Kertesz, A. (1976). Neologistic jargon aphasia (Vol. 3): Swets & Zeitlinger.

Buckingham, H. W., Jr., Avakian-Whitaker, H., & Whitaker, H. A. (1978). Alliteration and assonance in neologistic jargon aphasia. *Cortex,* 14(3), 365-380.

Burns, M. S., & Canter, G. J. (1977). Phonemic behavior of aphasic patients with posterior cerebral lesions. *Brain and Language,* 4(4), 492-507. doi: https://doi.org/10.1016/0093-934X(77)90041-4

Butterworth, B. (1992). Disorders of phonological encoding. *Cognition,* 42(1), 261-286. doi: http://dx.doi.org/10.1016/0010-0277(92)90045-J

Butterworth, B., Swallow, J., & Grimston, M. (1981). Chapter 5 - Gestures and Lexical Processes in Jargonaphasia A2 - BROWN, JASON W Jargonaphasia (pp. 113-124). New York: Academic Press.

Chang, E. F., Niziolek, C. A., Knight, R. T., Nagarajan, S. S., & Houde, J. F. (2013). Human cortical sensorimotor network underlying feedback control of vocal pitch. *Proceedings of the National Academy of Sciences*, 110(7), 2653-2658.

Cohen, L., & Dehaene, S. (1998). Competition between past and present. Assessment and interpretation of verbal perseverations. *Brain*, 121(9), 1641-1659.

Cohen, L., & Dehaene, S. (2004). Specialization within the ventral stream: the case for the visual word form area. *Neuroimage,* 22(1), 466-476, https://doi.org/10.1016/j.neuroimage.2003.12.049

Cohen, L., Dehaene, S., Vinckier, F., Jobert, A., & Montavont, A. (2008). Reading normal and degraded words: Contribution of the dorsal and ventral visual pathways. *Neuroimage,* 40, 353:366

Coltheart, M. (1978). Lexical access in simple reading tasks. *Strategies of information processing*, 151-216.

Coltheart, M. (1981). The MRC psycholinguistic database. *The Quarterly Journal of Experimental Psychology* Section A, 33(4), 497-505. doi: 10.1080/14640748108400805

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychol Rev*, 100(4), 589-608. doi: 10.1037/0033-295X.100.4.589

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychol Rev*, 108(1), 204-256.

Corbett, F., Jefferies, E., & Ralph, M. A. L. (2008). The use of cueing to alleviate recurrent verbal perseverations: Evidence from transcortical sensory aphasia. *Aphasiology*, 22(4), 363-382. doi: 10.1080/02687030701415245

Crisp, J., & Lambon Ralph, M. A. (2006). Unlocking the nature of the phonological-deep dyslexia continuum: the keys to reading aloud are in phonology and semantics*. J Cogn Neurosci,* 18(3), 348-362. doi: 10.1162/089892906775990543

Davis, C. J. (2005). N-Watch: A program for deriving neighborhood size and other psycholinguistic statistics. *Behavior Research Methods,* 37(1), 65-70. doi: 10.3758/BF03206399

Damasio A. R. (1992). Aphasia. *New England Journal of Medicine*, 326, 531–539.

Damian, M. F. (2003). Articulatory duration in single-word speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 29(3), 416–31.

Damian, M. F., & Martin, R. C. (1999). Semantic and phonological codes interact in single word production. Journal of Experimental Psychology: *Learning, Memory, and Cognition*, 25(2), 345.

Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of Semantic Context in the Naming of Pictures and Words. *Cognition,* 81(3), B77–B86.

De Zubicaray, G. I., McMahon, K. L., Eastburn, M. M., & Wilson, S. J. (2002). Orthographic/phonological facilitation of naming responses in the picture–word task: An event-related fMRI study using overt vocal responding. *Neuroimage*, 16(4), 1084-1093.

Dell, G. & Schwartz, M. (2011) Who's in and who's out? Inclusion criteria, model evaluation, and the treatment of exceptions in case series. *Cognitive Neuropsychology,* 28: 515–520.

Dell, G., Schwartz, M., Nozari, N., Faseyitan, O., & Branch Coslett, H. (2013). Voxel-based lesion parameter mapping: identifying the neural correlates of a computational model of word production. *Cognition,* 128, 380-396.

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*. 93:283:321.

Dell, G. S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Lang Cogn Process,* 5(4), 313-349.

Dell, G. S., & Reich, P. A. (1981) Stages in sentence production: An analysis of speech error data. *Journal of Verbal Learning and Verbal Behaviour,* 20, 611-629.

Dell, G. S., Martin, N., & Schwartz, M. F. (2007). A Case-Series Test of the Interactive Two-step Model of Lexical Access: Predicting Word Repetition from Picture Naming. *Journal of Memory and Language*, 56(4), 490-520. doi: 10.1016/j.jml.2006.05.007

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychol Rev,* 104(4), 801-838.

Demeyere N, Riddoch MJ, Slavkova ED, Bickerton W-L, & Humphreys GW. (2015). The Oxford Cognitive Screen (OCS): Validation of a stroke-specific short cognitive screening tool. *Psychological Assessment,* 27(3), 883–894.

Denes, P. B. (1963). On the Statistics of Spoken English. *The Journal of the Acoustical Society of America,* 35(6), 892-904. doi: doi:http://dx.doi.org/10.1121/1.1918622

Dronkers, N. F., & Baldo, J. (2010). Language: aphasia *Encyclopedia of neuroscience:* Elsevier Ltd.

Eaton, E., Marshall, J. & Pring, T. (2011). Mechanisms of change in the evolution of jargon aphasia. *Aphasiology,* 25(12), pp. 1543-1561. doi: 10.1080/02687038.2011.624584

Eaton, E., Marshall, J., & Pring, T. (2010). Like deja vu all over again: Patterns of perseveration in two people with jargon aphasia. *Aphasiology,* 24(9), 1017-1031. doi: Pii 918865637 10.1080/02687030903249343

Eaton, E., Marshall, J., & Pring, T. (2011). Mechanisms of change in the evolution of jargon aphasia. *Aphasiology*, 25(12), 1543-1561. doi: 10.1080/02687038.2011.624584

Edwards, E., Nagarajan, S. S., Dalal, S. S., Canolty, R. T., Kirsch, H. E., Barbaro, N. M., & Knight, R. T. (2010). Spatiotemporal imaging of cortical activation during verb generation and picture naming. *Neuroimage*, 50(1), 291-301.

Ellis, A. W., Miller, D., & Sin, G. (1983). Wernicke's aphasia and normal language processing: A case study in cognitive neuropsychology. *Cognition,* 15(1), 111-144. doi: https://doi.org/10.1016/0010-0277(83)90036-7

Fischer-Baum, S. (2013) Making sense of deviance: Identifying dissociating cases within the case series approach. *Cognitive Neuropsychology* 30:7-8, pages 597-617.

Fischer-Baum, S., & Rapp, B. (2012). Underlying cause(s) of letter perseveration errors. *Neuropsychologia,* 50(2), 305-318. doi: http://dx.doi.org/10.1016/j.neuropsychologia.2011.12.001

Foygel, D., & Dell, G. S. (2000). Models of Impaired Lexical Access in Speech Production. *Journal of Memory and Language,* 43(2), 182-216. doi: https://doi.org/10.1006/jmla.2000.2716

Frankel, T., Penn, C., & Ormond-Brown, D. (2007). Executive dysfunction as an explanatory basis for conversation symptoms of aphasia: A pilot study. *Aphasiology,* 21(6-8), 814-828.

Gerhand, S., & Barry, C. (1998). Word frequency effects in oral reading are not merely age-of-acquisition effects in disguise. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 24(2), 267-283. doi: 10.1037/0278-7393.24.2.267

Godbold, C. (2016). Non-word errors in jargon aphasia : exploring the underlying mechanisms. *Thesis (PhD.)* - University of Reading, School of Psychology & Clinical Language Sciences.

Godbold, C., Robson, H., & Bose, A. (2013). Patterns of Phonological Overlap between Non-word Error and Target in Jargon Aphasia. Procedia - *Social and Behavioral Sciences,* 94, 28-29. doi: http://dx.doi.org/10.1016/j.sbspro.2013.09.011

Goldrick, M. (2014). Phonological processing: The retrieval and encoding of word form information in speech production. *The Oxford handbook of language production,* 228-244.

Goldrick, M., & Blumstein, S. E. (2006). Cascading activation from phonological planning to articulatory processes: Evidence from tongue twisters. *Lang Cogn Process,* 21(6), 649-683. doi: 10.1080/01690960500181332

Goldrick, M., & Rapp, B. (2007). Lexical and post-lexical phonological representations in spoken production. *Cognition,* 102(2), 219-260.

Goodglass, H. (1992). Diagnosis of conduction aphasia. In: Kohn S. *Conduction aphasia*. Hillsdale, N.J: Lawrence Erlbaum Associates. pp. 39–49.

Goodglass, H., Kaplan, E., & Barresi, B. (2001). *Boston diagnostic aphasia examination* (3rd ed.). Philadelphia: Lippincott Williams & Wilkins.

Gotts, S. J. (2016). Incremental learning of perceptual and conceptual representations and the puzzle of neural repetition suppression. *Psychonomic Bulletin & Review,* 23(4), 1055-1071. doi: 10.3758/s13423-015-0855-y

Gotts, S. J., della Rocchetta, A. I., & Cipolotti, L. (2002). Mechanisms underlying perseveration in aphasia: evidence from a single case study. *Neuropsychologia,* 40(12), 1930-1947. doi: Pii S0028-3932(02)00067-2Doi 10.1016/S0028-3932(02)00067-2

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception & Psychophysics,* 47(2), 191-198. doi: 10.3758/BF03205983

Graves, W. W., Grabowski, T. J., Mehta, S., & Gordon, J. K. (2007). A neural signature of phonological access: distinguishing the effects of word frequency from familiarity and length in overt picture naming. *Journal of cognitive neuroscience,* 19(4), 617-631.

Halpern, H. (1965). Effect of Stimulus Variables on Verbal Perseveration of Dysphasic Subjects. *Perceptual and Motor Skills,* 20(2), 421-429. doi: 10.2466/pms.1965.20.2.421

Hanley, J. R., & Kay, J. R(1997). An Effect of Imageability on the Production of Phonological Errors in Auditory Repetition. *Cognitive Neuropsychology,* 14(8), 1065-1084. doi: 10.1080/026432997381277

Hanley, J. R., Dell, G. S., Kay, J., & Baron, R. (2004). Evidence for the involvement of a nonlexical route in repetition of familiar words: a comparison of single and dual route models of auditory word repetition. *Cognitive neuropsychology,* 21(2/3/4) 147-158.

Hanley, J. R., Kay, J., & Edwards, M. (2002). Imageability effects, phonological errors, and the relationship between auditory repetition and picture naming: Implications for models of auditory repetition. *Cognitive Neuropsychology,* 19(3), 193-206. doi: 10.1080/02643290143000132

Helm-Estabrooks, N., Ramage, A., Bayles, K. A., & Cruz, R. (1998). Perseverative behaviour in fluent and non-fluent aphasic adults*. Aphasiology,* 12(7-8), 689-698. doi: Doi 10.1080/02687039808249566

Hickok, G., Buchsbaum, B., Humphries, C., & Muftuler, T. (2003). Auditory–motor interaction revealed by fMRI: speech, music, and working memory in area Spt. *Journal of cognitive neuroscience,* 15(5), 673-682.

Hickok, G., & Poeppel, D. (2004). Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language. *Cognition*, 92(1-2), 67-99. doi: 10.1016/j.cognition.2003.10.011

Hillis, A. E. (2007). Aphasia. *Neurology*, 69(2), 200.

Hillis, A. E., Boatman, D., Hart, J., & Gordon, B. (1999). Making sense out of jargon. *Neurology*, 53(8), 1813.

Hirsh, K. W. (1998). Perseveration and Activation in Aphasic Speech Production. *Cognitive Neuropsychology,* 15(4), 377-388. doi: 10.1080/026432998381140

Hodgson, C., Schwartz, M. F., Schnur, T. T., & Brecher, A. (2005). Facilitation and interference in phonological blocked-cyclic naming. *Brain and Language*, 95, 46-47.

Hoffman, P., Jefferies, B., & Lambon Ralph, M. A. (2011). Remembering 'zeal' but not 'thing': Reverse frequency effects as a consequence of deregulated semantic processing. *Neuropsychologia,* 49(3), 580-584. doi.org/10.1016/j.neuropsychologia.2010.12.036

Hojo, K., Watanabe, S., Tasaki, H., Sato, T., & Metoki, H. (1985). Localization of lesions in aphasia--clinical-CT scan correlations (Part III): Paraphasia and meaningless speech. *No to shinkei= Brain and nerve,* 37(2), 117-126.

Houde, J. F., & Chang, E. F. (2015). The cortical computations underlying feedback control in vocal production. *Current Opinion in Neurobiology,* 33, 174-181. doi:10.1016/j.conb.2015.04.006

Hudson, A. J. (1968). Perseveration. *Brain,* 91(3), 571-582. doi: 10.1093/brain/91.3.571

Hulme, C., Roodenrys, S., Schweickert, R., Brown, G. D., Martin, M., & Stuart, G. (1997). Word-frequency effects on short-term memory tasks: evidence for a redintegration process in immediate serial recall. *J Exp Psychol Learn Mem Cogn,* 23(5), 1217-1232.

Indefrey, P. (2011). The Spatial and Temporal Signatures of Word Production Components: A Critical Update. Frontiers in Psychology, Indefrey P. (2011). The spatial and temporal signatures of word production components: a critical update. *Frontiers in psychology*, *2*, 255. doi:10.3389/fpsyg.2011.00255

Jefferies, E., Crisp, J., & Ralph, M. A. L. (2006). The impact of phonological or semantic impairment on delayed auditory repetition: Evidence from stroke aphasia and semantic dementia. *Aphasiology,* 20(9), 963-992. doi: 10.1080/02687030600739398

Jefferies, E., Patterson, K., Jones, R. W., & Lambon Ralph, M. A. (2009). Comprehension of concrete and abstract words in semantic dementia. *Neuropsychology,* 23(4), 492-499. doi: 10.1037/a0015452

Kay, J., Lesser, R., & Coltheart, M. (1996). Psycholinguistic assessments of language processing in aphasia (PALPA): An introduction. *Aphasiology,* 10(2), 159-180. doi: 10.1080/02687039608248403

Kertesz, A., & Sheppard, A. N. N. (1981). The epidemiology of aphasic and cognitive impairment in stroke: age, sex, aphasia type and laterality differences. *Brain: a journal of neurology*, *104*(Pt 1), 117-128.

Kertesz, A. (1981). Chapter 4 - The Anatomy of Jargon A2 - BROWN, JASON W *Jargonaphasia* (pp. 63-112): Academic Press.

Kertesz, A., & Benson, D. F. (1970). Neologistic Jargon: A Clinicopathological Study. *Cortex,* 6(4), 362-386. doi: https://doi.org/10.1016/S0010-9452(70)80002-8

Kertesz, Andrew. (1982). The Western aphasia battery. New York: Grune & Stratton.

Kinsbourne, M., & Warrington, E. K. (1963). Jargon aphasia. *Neuropsychologia,* 1(1), 27-37. doi: http://dx.doi.org/10.1016/0028-3932(63)90010-1

Kittredge, A. K., Dell, G. S., Verkuilen, J., & Schwartz, M. F. (2008). Where is the effect of frequency in word production? Insights from aphasic picture-naming errors. *Cognitive Neuropsychology,* 25(4), 463-492. doi: 10.1080/02643290701674851

Kohen, F., Benetello, A., Guerrero, M., Kalinyak-Fliszar, M., & Martin, N. (2012). Verbal Perseveration in Aphasia during Word-String Repetition: Effects of a Filled versus Silent Interstimulus Interval. http://aphasiology.pitt.edu/2395/

Kohn, S. E. (1984). The nature of the phonological disorder in conduction aphasia. *Brain and Language,* 23(1), 97-115.

Kohn, S. E., & Smith, K. L. (1994). Distinctions between two phonological output deficits. Applied Psycholinguistics, 15(1), 75-95.

Kohn, S. E., & Smith, K. L. (1994). Evolution of impaired access to the phonological lexicon. *J Neurolinguistics*, 8(4), 267-288. doi: https://doi.org/10.1016/0911-6044(94)90013-2

Kohn, S. E., Smith, K. L., & Alexander, M. P. (1996). Differential recovery from impairment to the phonological lexicon. *Brain and Language, 52*(1), 129-149. doi: 10.1006/brln.1996.0007

Kreisler, A., Godefroy, O., Delmaire, C., Debachy, B., Leclercq, M., Pruvo, J. P., & Leys, D. (2000). The anatomy of aphasia revisited. *Neurology,* 54(5), 1117.

Laszlo, S., & Federmeier, K. D. (2007). Better the DVL You Know: Acronyms Reveal the Contribution of Familiarity to Single-Word Reading. *Psychological Science,* 18(2), 122-126. doi: 10.1111/j.1467-9280.2007.01859.x

Lecours, A. R., Osborn, E., Travis, L., Rouillon, F., & Lavall´E-Huynh, G. (1981). Chapter 2 - Jargons1 A2 - BROWN, JASON W *Jargonaphasia* (pp. 9-38): Academic Press.

Levelt, W. J. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition,* 42(1-3), 1-22.

Levelt, W. J. (2001). Spoken word production: A theory of lexical access. *Proceedings of the National Academy of Sciences*, 98 (23) 13464-13471; DOI: 10.1073/pnas.231459498

Levelt, W. J., Praamstra, P., Meyer, A. S., Helenius, P., & Salmelin, R. (1998). An MEG study of picture naming. *Journal of cognitive neuroscience*, 10(5), 553-567.

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behav Brain Sci,* 22(1), 1-38; discussion 38-75.

Marshall, J. (2006). Jargon aphasia: What have we learned? *Aphasiology,* 20(5), 387-410. doi: 10.1080/02687030500489946

Marshall, J., Pring, T., Chiat, S., & Robson, J. (1996). Calling a salad a federation: an investigation of semantic Jargon. Part 1- Nouns. *Journal of Neurolinguistics,* 9, 251-260.

Marshall, J., Pring, T., Chiat, S., & Robson, J. (2001). When Ottoman is Easier than Chair: An Inverse Frequency Effect in Jargon Aphasia. *Cortex,* 37(1), 33-53. doi.org/10.1016/S0010-9452(08)70556-2

Marshall, J., Robson, J., Pring, T., & Chiat, S. (1998). Why Does Monitoring Fail in Jargon Aphasia? Comprehension, Judgment, and Therapy Evidence. *Brain and Language*, 63(1), 79-107. doi: https://doi.org/10.1006/brln.1997.1936

Martin, N., & Dell, G. S. (2004). Perseverations and anticipations in aphasia: primed intrusions from the past and future. *Semin Speech Lang,* 25(4), 349-362. doi: 10.1055/s-2004-837247

Martin, N., & Dell, G. S. (2007). Common mechanisms underlying perseverative and non-perseverative sound and word substitutions. *Aphasiology,* 21(10-11), 1002-1017. doi: 10.1080/02687030701198346

Martin, N., & Saffran, E. M. (1997). Language and auditory-verbal short-term memory impairments: Evidence for common underlying processes. *Cognitive Neuropsychology,* 14(5), 641-682. doi: 10.1080/026432997381402

Martin, N., & Saffran, E. M. (2002) The relationship of input and output phonological processing: An evaluation of models and evidence to support them, *Aphasiology,* 16:1-2, 107-150, DOI: 10.1080/02687040143000447

Martin, R., Breedin, S., & Damien, M. (1999). The relation of phoneme discrimination, lexical access and short-term memory: a case-study and interactive activation account. *Cognitive Neuropsychology,* 70, 437-482.

McCarthy, R., & Warrington, E. K. (1984). A two-route model of speech production. Evidence from aphasia. *Brain,* 107 (Pt 2), 463-485.

McCloskey, M., Macaruso, P., & Rapp, B. (2006). Grapheme-to-lexeme feedback in the spelling system: Evidence from a dysgraphic patient. *Cognitive Neuropsychology*, 23(2), 278-307. doi: 10.1080/02643290442000518

Mesgarani N., Cheung, C., Johnson, K., & Chang, E. F. (2014). Phonetic feature encoding in human superior temporal gyrus. *Science.* 343(6174):1006-10. doi: 10.1126/science.1245994.

Meteyard, L., & Bose, A. (2017). What Does a Cue Do? Comparing Phonological and Semantic Cues for Picture Naming in Aphasia. *The Journal of Speech, Language and Hearing Research.* Doi: https://doi.org/10.1044/2017_JSLHR-L-17-0214

Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: where are they? *J Exp Psychol Gen,* 118(1), 43-71.

Moses, M. S., Nickels, L. A., & Sheard, C. (2004a). Disentangling the web: Neologistic perseverative errors in jargon aphasia. *Neurocase,* 10(6), 452-461. doi: 10.1080/13554790490894057

Moses, M. S., Nickels, L. A., & Sheard, C. (2004b). I'm sitting here feeling aphasic! A study of recurrent perseverative errors elicited in unimpaired speakers. *Brain and Language,* 89(1), 157-173. doi: 10.1016/s0093-934x(03)00364-x

Moses, M. S., Nickels, L. A., & Sheard, C. (2007). Chips, cheeks and carols: A review of recurrent perseveration in speech production. *Aphasiology,* 21(10-11), 960-974. doi: 10.1080/02687030701198254

Moses, M. S., Sheard, C., & Nickels, L. A. (2007). Insights into recurrent perseveration errors in aphasia: A case series approach. *Aphasiology,* 21:10-11, 975-1001, DOI: 10.1080/02687030701198312.

Nickels, L., & Howard, D. (1995). Aphasic naming: What matters? *Neuropsychologia*, 33(10), 1281-1303. doi: http://dx.doi.org/10.1016/0028-3932(95)00102-9

Nickels, L., & Howard, D. (2004). Dissociating Effects of Number of Phonemes, Number of Syllables, and Syllabic Complexity on Word Production in Aphasia: It's the Number of Phonemes that Counts. *Cognitive Neuropsychology,* 21(1), 57-78.

Nickels, L., Howard, D., & Best, W. (2011). On the use of different methodologies in cognitive neuropsychology: Drink deep and from several sources. *Cognitive Neuropsychology*, 28: 475–485

Niziolek, C. A., & Kiran, S. (2018). Assessing speech correction abilities with acoustic analyses: Evidence of preserved online correction in persons with aphasia. *International Journal of Speech-Language Pathology*, 20(6), 659-668.

Nozari, N., & Dell, G. S. (2013). How damaged brains repeat words: A computational approach. *Brain and Language,* 126(3), 327-337. doi: https://doi.org/10.1016/j.bandl.2013.07.005

Nozari, N., and Dell, G. (2013). How damaged brains repeat words: A computational approach. *Brain and Language.* 126(3), 327-337. https://doi.org/10.1016/j.bandl.2013.07.005

Nozari, N., Kitteridge, A. K., Dell, G. S., & Schwartz, M. F., (2010). Naming and repetition in aphasia: Steps, routes and frequency effects*. Journal of Memory and Language, 1*;63(4):541-559. doi: 10.1016/j.jml.2010.08.001

O'Connell, P. F. (1981). Neologistic jargon aphasia: A case report. *Brain and Language,* 12(2), 292-302. doi: https://doi.org/10.1016/0093-934X(81)90020-1

Olson, A. C., Romani, C., & Halloran, L. (2007). Localizing the deficit in a case of jargonaphasia. *Cognitive Neuropsychology*, 24(2), 211-238. doi: 10.1080/02643290601137017

Olson, A., Halloran, E., & Romani, C. (2015). Target/error overlap in jargonaphasia: The case for a one-source model, lexical and non-lexical summation, and the special status of correct responses. *Cortex,* 73, 158-179. doi: http://dx.doi.org/10.1016/j.cortex.2015.06.028

Panzeri, M., Semenza, C., & Butterworth, B. (1987). Compensatory processes in the evolution of severe jargon aphasia. *Neuropsychologia,* 25(6), 919-933. doi: http://dx.doi.org/10.1016/0028-3932(87)90096-0

Papagno, C., & Basso, A. (1996). Perseveration in Two Aphasic Patients. *Cortex,* 32(1), 67-82. doi: 10.1016/s0010-9452(96)80017-7

Pate, D. S., Saffran, E. M., & Martin, N. (1987). Specifying the nature of the production impairment in a conductionxs aphasic: A case study. *Lang Cogn Process,* 2(1), 43-84. doi: 10.1080/01690968708406351

Patterson, K. E., & Morton, J. (1985). From orthography to phonology: An attempt at an old interpretation. *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading*, 335-359.

Patterson, K., Graham, N., & Hodges, J. R. (1994). The impact of semantic memory loss on phonological representations. *J Cogn Neurosci,* 6(1), 57-69. doi: 10.1162/jocn.1994.6.1.57

Pekkala, S., Albert, M. L., Spiro Iii, A., & Erkinjuntti, T. (2008). Perseveration in Alzheimer's disease. *Dementia and geriatric cognitive disorders,* 25(2), 109-114.

Price, C. (1998). The functional anatomy of word comprehension and production. *Trends in Cognitive Neuroscience,* 2(8), pp 281-288.

Piai, V., & Knight, R. (2017). Lexical selection with competing distractors: Evidence from left temporal lobe lesions. *Psychonomic Bulletin and Review,* 25(2), 710:717. Doi:

Pilkington, E., Keidel, J., Kendrick, L. T., Saddy, J. D., Sage, K., & Robson, H. (2017). Sources of Phoneme Errors in Repetition: Perseverative, Neologistic, and Lesion Patterns in Jargon Aphasia. *Frontiers in Human Neuroscience*, 11(225). doi: 10.3389/fnhum.2017.00225

Pilkington, E., Sage, K., Saddy, D. and Robson, H. (2019) What can repetition, reading and naming tell us about Jargon Aphasia? *Journal of Neurolinguistics,* 49. pp. 45-56. ISSN 0911-6044 doi: https://doi.org/10.1016/j.jneuroling.2018.08.003

Plaut, D. C., & Kello, C. T. (1999). The emergence of phonology from the interplay of speech comprehension and production: A distributed connectionist approach. *The emergence of language.* (pp. 381-415). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychol Rev,* 103(1), 56-115. doi: 10.1037/0033-295X.103.1.56

Purcell, R., Lambon-Ralph, M., & Sage, K. (2018). Investigating the language, cognition and self-monitoring abilities of speakers with jargon output. *Aphasiology,* DOI: 10.1080/02687038.2018.1532070

Rapp, B. (2011) Case series in cognitive neuropsychology: Promise, perils, and proper perspective, *Cognitive Neuropsychology*, 28:7, 435-444, DOI: 10.1080/02643294.2012.697453

Rayner, K., & Duffy, S. A. (1986). Lexical complexity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity. *Memory & Cognition,* 14(3), 191-201. doi: 10.3758/BF03197692

RCSLT (2009) RCSLT RESOURCE MANUAL FOR COMMISSIONING AND PLANNING SERVICES FOR SLCN Aphasia. file:///C:/Users/zc872735/Downloads/resource-manual-aphasia.pdf

Richardson, F. M., Seghier, M. L., Leff, A. P., Thomas, M. S. C., & Price, C. (2011). *Journal of Neuroscience, 31*(22) 8239:8247. DOI: https://doi.org/10.1523/JNEUROSCI.6519-10.2011

Robin, D. A., & Schienberg, S. (1990). Subcortical lesions and aphasia. *Journal of Speech and Hearing Disorders,* 55(1), 90-100.

Robinson, G. A., Butterworth, B., & Cipolotti, L. (2015). "My Mind Is Doing It All": No "Brake" to Stop Speech Generation in Jargon Aphasia. *Cogn Behav Neurol,* 28(4), 229-241. doi: 10.1097/wnn.0000000000000080

Robson, H., Grube, M., Lambon Ralph, M. A., Griffiths, T. D., & Sage, K. (2013). Fundamental deficits of auditory perception in Wernicke's aphasia. *Cortex,* 49(7), 1808-1822. doi: 10.1016/j.cortex.2012.11.012

Robson, H., Keidel, J. L., Lambon Ralph, M. A., & Sage, K. (2012). Revealing and quantifying the impaired phonological analysis underpinning impaired comprehension in Wernicke's aphasia. *Neuropsychologia,* 50(2), 276-288. doi: https://doi.org/10.1016/j.neuropsychologia.2011.11.022

Robson, H., Pilkington, E., Evans, L., DeLuca, V. and Keidel, J. (2017) Phonological and semantic processing during comprehension in Wernicke's aphasia: a N400 and Phonological Mapping Negativity study. *Neuropsychologia*, 100. pp. 144-154. ISSN 0028-3932 doi: https://doi.org/10.1016/j.neuropsychologia.2017.04.012

Robson, H., Sage, K. and Lambon Ralph, M. A. (2012) Revealing and quantifying the impaired phonological analysis underpinning impaired comprehension in Wernicke's aphasia. *Neuropsychologia,* 50 (2). pp. 276-288. ISSN 0028-3932 doi: https://doi.org/10.1016/j.neuropsychologia.2011.11.022

Robson, H., Sage, K. and Lambon Ralph, M. A. (2012) Wernicke's aphasia reflects a combination of acoustic-phonological and semantic control deficits: A case-series comparison of Wernicke's aphasia, semantic dementia and semantic aphasia. *Neuropsychologia,* 50 (2). pp. 266-275. ISSN 0028-3932 doi: https://doi.org/10.1016/j.neuropsychologia.2011.11.021

Robson, H., Specht, K., Beaumont, H., Parkes, L. M., Sage, K., Lambon Ralph, M. A., & Zahn, R. (2017). Arterial spin labelling shows functional depression of non-lesion tissue in chronic Wernicke's aphasia*. Cortex,* 92: 249–260.

Robson, J. O., Marshall, J., Pring, T. I. M., & Chiat, S. (1998). Phonological naming therapy in jargon aphasia: Positive but paradoxical effects. *Journal of the International Neuropsychological Society,* 4(06), 675-686.

Robson, J., Marshall, J., Chiat, S., & Pring, T. (2001). Enhancing communication in jargon aphasia: a small group study of writing therapy. *International Journal of Language & Communication Disorders,* 36(4), 471-488. doi: 10.1080/13682820110089371

Robson, J., Pring, T., Marshall, J., & Chiat, S. (2003). Phoneme frequency effects in jargon aphasia: a phonological investigation of nonword errors. *Brain and Language,* 85(1), 109-124.

Robson, J., Pring, T., Marshall, J., Morrison, S., & Chiat, S. (1998). Written communication in undifferentiated jargon aphasia: a therapy study. *International Journal of Language & Communication Disorders*, 33(3), 305-328. doi: 10.1080/136828298247767

Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition,* 64(3), 249-284. doi: https://doi.org/10.1016/S0010-0277(97)00027-9

Roelofs, A. (2004). Seriality of phonological encoding in naming objects and reading their names. *Mem. Cognit.* 32, 212–222. doi: 10.3758/BF03196853

Roelofs, A. (2014). A dorsal-pathway account of aphasic language production: The WEAVER++/ARC model. *Cortex,* 59, 33-48. doi: https://doi.org/10.1016/j.cortex.2014.07.001

Romani, C., Galluzzi, C., & Olson, A. (2011). Phonological–lexical activation: A lexical component or an output buffer? Evidence from aphasic errors. *Cortex,* 47(2), 217-235. doi: https://doi.org/10.1016/j.cortex.2009.11.004

Rorden, C, & Brett, M. (2000) Stereotaxic display of brain lesions. *Behavioural Neurology* 12(4), 191-200.

Sampson, M., & Faroqi-Shah, Y. (2011). Investigation of self-monitoring in fluent aphasia with jargon. *Aphasiology*. 25:4, 505-528, doi: 10.1080/02687038.2010.523471

Sandson, J., & Albert, M. L. (1984). Varieties of perseveration. *Neuropsychologia,* 22(6), 715-732.

Sandson, J., & Albert, M. L. (1987). Perseveration in behavioral neurology. *Neurology*, 37(11), 1736-1736.

Santo-Pietro, M. J. S., & Rigrodsky, S. (1986). Patterns of oral-verbal perseveration in adult aphasics. *Brain and Language*, 29(1), 1-17. doi: http://dx.doi.org/10.1016/0093-934X(86)90030-1

Schwartz, M. and Dell, G. 2010. Case series investigations in cognitive neuropsychology. *Cognitive Neuropsychology,* 27: 477–494.

Schwartz, M. F., Dell, G. S., & Martin, N. (2004). Testing the interactive two-step model of lexical access: Part I. picture naming. *Brain and Language,* 91(1), 71-72. doi: http://dx.doi.org.idpproxy.reading.ac.uk/10.1016/j.bandl.2004.06.039

Schwartz, M. F., Dell, G. S., Martin, N., Gahl, S., & Sobel, P. (2006). A case-series test of the interactive two-step model of lexical access: Evidence from picture naming. *Journal of Memory and Language,* 54(2), 228-264. doi: http://dx.doi.org/10.1016/j.jml.2005.10.001

Schwartz, M. F., Saffran, E. M., Bloch, D. E., & Dell, G. S. (1994). Disordered Speech Production in Aphasic and Normal Speakers. *Brain and Language,* 47(1), 52-88. doi: https://doi.org/10.1006/brln.1994.1042

Schwartz, M. F., Wilshire, C. E., Gagnon, D. A., & Polansky, M. (2004). Origins of nonword phonological errors in aphasic picture naming. *Cognitive Neuropsychology,* 21(2-4), 159-186. doi: 10.1080/02643290342000519

Seghier, M. L., Ramlackhansingh, A., Crinion, J., Leff, A. P., & Price, C. J. (2008). Lesion identification using unified segmentation-normalisation models and fuzzy clustering. *Neuroimage,* 41(4), 1253-1266.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychol Rev,* 96(4), 523-568. doi: 10.1037/0033-295X.96.4.523

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. *Journal of Memory and Language,* 54(2), 199–227.

Schnur, T. T., Schwartz, M. F., Kimberg, D. Y., Hirshorn, E., Coslett, H. B., & Thompson-Schill, S. L. (2009). Localizing interference during naming: convergent neuroimaging and neuropsychological evidence for the function of Broca's area. *Proceedings of the National Academy of Sciences of the United States of America,* 106(1), 322–327.

Stark, J. (2007). A review of classical accounts of verbal perseveration and their modern-day relevance. *Aphasiology,* 21(10-11), 928-959. doi: 10.1080/02687030701198239

Stark. J. (2017) Perseveration: Clinical Features and Considerations for Treatment. In Coppens, P., & Patterson, J. (1st Ed.) *Aphasia Rehabilitation, Clinical Challenges.* (Pp3-43).

Strain, E., Patterson, K., & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(5), 1140-1154. doi: 10.1037/0278-7393.21.5.1140

Strain, E., Patterson, K., & Seidenberg, M. S. (2002). Theories of word naming interact with spelling--sound consistency. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 28(1), 207-214. doi: 10.1037/0278-7393.28.1.207

Stuss, D. T., Alexander, M. P., Hamer, L., Palumbo, C., Dempster, R., Binns, M., . . . Izukawa, D. (1998). The effects of focal anterior and posterior brain lesions on verbal fluency. *Journal of the International Neuropsychological Society,* 4(3), 265-278.

Vitevitch, M. S. (2002). The Influence of Phonological Similarity Neighborhoods on Speech Production*. Journal of Experimental Psychology. Learning, Memory, and Cognition,* 28(4), 735-747. doi: 10.1037//0278-7393.28.4.735

Vitevitch, M.S. & Luce, P.A. (2004). A Web-based interface to calculate phonotactic probability for words and nonwords in English. *Behavior Research Methods, Instruments, & Computers. 36*: 481. https://doi.org/10.3758/BF03195594

Vitkovitch, M., & Humphreys, G. W. (1991). Perseverant responding in speeded naming of pictures: It's in the links*. Journal of Experimental Psychology: Learning, Memory, and Cognition,* 17(4), 664-680. doi: 10.1037/0278-7393.17.4.664

Wang, J., Mathalon, D. J., Roach, B. J., Reilly, J., Keedy, S. K., Sweeny, J. K., & Ford, J. M. (2014). Action planning and predictive coding when speaking. *Neuroimage,* 91, 91-98. Doi: https://doi.org/10.1016/j.neuroimage.2014.01.003

Warrington, E. K., & James, M. (1991). Visual Object and Space Perception Battery (VOSP). Bury St. Edmunds (UK): Thames Valley Test Company

Weekes, B. S. (1997). Differential Effects of Number of Letters on Word and Nonword Naming Latency. *The Quarterly Journal of Experimental Psychology* Section A, 50(2), 439-456. doi: 10.1080/713755710

Weinstein, E. A. (1981). Chapter 7 - Behavioral Aspects of Jargonaphasia A2 - BROWN, JASON W *Jargonaphasia* (pp. 139-149): Academic Press.

Wilshire, C. E., & McCarthy, R. A. (1996). Experimental investigations of an impairment in phonological encoding. *Cognitive Neuropsychology,* 13(7), 1059-1098.

Wilshire, C. E. & Saffran, E. M. (2005). Contrasting effects of phonological priming in aphasic word production. *Cognition,* 95(1), 31-71. Doi: https://doi.org/10.1016/j.cognition.2004.02.004

Yamadori, A. (1981). Verbal perseveration in aphasia. *Neuropsychologia,* 19(4), 591-594.

Chapter 8. Appendices

8.1 *Appendix 1*

Chapter 3 repetition and reading word sets.

Reading/Repetition
episode
theory
elbow
hotel
potato
woe
character
wheat
folly
tribute
gravity
valour
irony
axe
funnel
tractor
crisis
length
battle
clue
concept
spider
village
deed
gravy
plea
dogma
monkey
manner
realm
slope
alcohol
member
satire
window
treason
drum
mercy
radio
cart

pupil
miracle
onion
hospital
audience
quality
attitude
elephant
wrath
pig
tobacco
principle
session
plane
student
summer
marriage
feather
bonus
pact
opinion
coffee
pill
analogy

8.2 ***Appendix 2***

University of Reading School of Psychology and Clinical Languages School Ethics application.

University of Reading

Research Ethics Committee
School of Psychology and Clinical Language Sciences

SECTION 1: APPLICATION DETAILS

1.1 Project and Dates

Project title: Jargon Busting: The cognitive and neurobiological mechanisms underpinning Jargon Aphasia and Perseveration

Date of submission: Click here to enter a date. Start date: 01-Apr-2016 End date: 31-Aug-2017

1.2 Applicant Details

Principal Investigator

Name:	Holly Robson	Position:	Academic Staff
Institution/Department:	Psychology and Clinical Language Sciences	Email:	h.v.robson@reading.ac.uk
Office room number:	g64	Internal tel.:	7467
		Other tel.:	[redacted]

(Please note that an undergraduate or postgraduate student cannot be a named principal investigator for research ethics purposes. The supervisor must be declared as Principal Investigator)

Other Applicants

Name:	Emma Pilkingtom	Position:	Student
Institution/Department:	Psychology and Clinical language Sciences	Email:	e.c.pilkington@pgr.reading.ac.uk
Name:	Click here to enter text.	Position:	Choose an item.
Institution/Department:	Click here to enter text.	Email:	Click here to enter text.
Name:	Click here to enter text.	Position:	Choose an item.
Institution/Department:	Click here to enter text.	Email:	Click here to enter text.
Name:	Click here to enter text.	Position:	Choose an item.
Institution/Department:	Click here to enter text.	Email:	Click here to enter text.
Name:	Click here to enter text.	Position:	Choose an item.
Institution/Department:	Click here to enter text.	Email:	Click here to enter text.
Name:	Click here to enter text.	Position:	Choose an item.
Institution/Department:	Click here to enter text.	Email:	Click here to enter text.

1.3 Project Submission Declaration

I confirm that to the best of my knowledge I have made known all information relevant to the Research Ethics Committee and I undertake to inform the Committee of any such information which subsequently becomes available whether before or after the research has begun.

I understand that it is a legal requirement that both staff and students undergo Disclosure and Barring Service checks when in a position of trust (i.e. when working with children or vulnerable adults).

I confirm that if this project is an interventional study, a list of names and contact details of the participants in this project will be compiled and that this, together with a copy of the Consent Form, will be retained within the School for a minimum of five years after the date that the project is completed.

[redacted] *Investigator)*	19-May-2016 *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*
(Signed, Other named investigator)	Click here to enter a date. *Date*

1.4 University Research Ethics Committee Applications

Projects expected to require review by the University Research Ethics Committee (such as, for example, research involving NHS patients, research involving potential for distress to participants) must be reviewed by the Chair of the School Ethics Committee or the Head of School before submission. Please ask PCLSethics@reading.ac.uk if unsure whether your project needs UREC approval.

	Click here to enter a date.
(Signed, Chair of School Research Ethics Committee)	*Date*
	Click here to enter a date.
(Signed, Head of School)	*Date*

1.5 External Research Ethics Committees

Please provide details below of other external research ethics committees to which this project has been submitted, or from whom approval has already been granted (e.g. NHS Committee)

Name of committee	Date of submission/approval	Reference	Status
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter a date.	Click here to enter text.	Click here to enter text.

SECTION 2: PROJECT DETAILS

2.1 Lay Summary

Please provide a summary of the project in non-specialist terms, which includes a description of the scientific background to the study (existing knowledge), the scientific questions the project will address and a justification of these. Please note that the description must be sufficient for the committee to take a reasonable view on the likely scientific rigour and value of the project.

After a stroke some people find it hard to stop themselves saying words which do not make sense. Most people know what they want to say but the words come out jumbled up ("jargon speech"). Jargon speech (or jargon aphasia) is extremely frustrating for the stroke survivor. Perseveration, the repetition of a previously produced response in an inappropriate context, often co-occurs in jargon aphasia. Current research suggests that jargon speech and perseveration is caused by a weakness in activating and selecting the current target information. Specifically, the person with jargon aphasia is unable to activate the right sounds in the right order, which causes speech to come out in a disordered manner (failure to activate hypothesis). An alternative view is that the person with jargon aphasia cannot clear one word quickly enough before the next word arrives and these words get mixed up (failure to inhibit hypothesis). Recent evidence largely supports the activation account; however, the inhibitory hypothesis remains underexplored. Furthermore, it is unclear whether these two separate accounts are mutually exclusive, or if both processes can be manipulated to help elicit more accurate speech in jargon aphasia.

This study wants to understand more about the causes of jargon speech by exploring the influence of activatory and inhibitory processes. In doing so we can establish ways that therapy can more effectively help reduce jargon speech and perseverations. Firstly we will manipulate different word properties to investigate the role that these have on accuracy. These will include age of acquisition, word length and imagability amongst others. Current literature suggests that these factors have some influence on accuracy of word production in jargon aphasia (Santo-Pietro & Rigrodksy, 1982; Hirsh, 1998); however, results are inconsistent and the majority of work has focused on single case studies or small case series analyses. This study will explore the influence of various word properties on accuracy of spoken production in a group of people with varying degrees of jargon aphasia. Secondly, we will manipulate the activity during trials on tasks of reading, repetition and naming, in order to investigate the role of inhibitory mechanisms in spoken word production. We will use matching and contrastive modes of presentation for inter-trial tasks. For example, in reading, the tasks between reading words aloud will include a visual processing task (in line with the visual processing element required for successful reading) and an auditory processing task (not directly relevant for successful reading). The same approach will be applied to naming and repetition. Some of these inter-trial tasks will require an overt response from the participant and some will not. This will enable us to evaluate whether we can manipulate inhibitory processes to provide an optimum environment for the person with jargon aphasia to select and organise the sound segments they need to produce words accurately.

This study will investigate the accuracy of spoken word production and severity of jargon and perseverations when activatory and inhibitory processes are manipulated.

This will allow us to answer the following questions:

To what extent do activatory and inhibitory mechanisms influence accurate word production in jargon aphasia and perseveration?

Is there a difference in the influence of activatory/inhibitory mechanisms depending on the severity of jargon aphasia?

Whether jargon and perseveration are the result of the same mechanim(s) and subject to the same rate of change dependent on how we manipulate inhibitory/activatory mechanisms.

Can we manipulate activatory and inhibitory processes to faciliate more accurate spoken word production in jargon aphasia?

Answering these questions will provide us with new information about the source and nature of jargon aphasia and indicate how to maximise the selection and production of sound segments in order to facilitate accurate word production in these individuals.

References:

Hirsh, K.W. (1998). Perseveration and activation in aphasic speech production. Cognitive Neuropsychology, 15(4), 377-388.

Pietro, M.J.S., & Rigrodsky, S. (1986). Patterns of oral-verbal perseveration in adult aphasics. Brain and Language, 29(1), 1-17.

2.2 Procedure

Please briefly describe what the study will involve for your participants and the instruments and methodology to be undertaken.

Participants with jargon aphasia following cerebrovascular accident (CVA) will be recruited from stroke clubs and the clinical language sciences adult research registry and from collaborating sites in Manchester and Sheffield. As with the UoR database, participants from these sites have indicated an interest in hearing about future research studies.

All participants will be approached by a familiar individual and invited to hear more about the research study, see below for recruitment proceedure. During initial visits individuals may undertake a short screening test to confirm suitability for the current study.

Study Proceedure: Participants will be visited in their own homes for neuropsychological testing and data collection for studies 1 and 2. Sessions for both may will take between 1 and 2 hours, depending on the participant's preference. Up to 6 data collection session may be required.

For study 1 we will generate word sets which vary on different psycholinguistic parameters, across modalities of reading, repetition and picture naming. Test items will be presented via laptop computer. Participants will be asked to either read/repeat/name the target items whilst being audio recorded. Participant responses will also be phonetically transcribed during the session, and checked with the audio recording after the session. We will then use within subject's t tests/Wilcoxon tests to identify if there is a significant difference in the accuracy of participant responses depending on the word set and modality.

Study 2 will involve the generation of different word sets depending on outcomes from study1. Words will be presented in different modalities (naming/reading/repeating). During the word production tasks, participants will be also be given a non-language task, which will either coincide with or oppose the mode of presentation of the task at hand. This task will alternate with trials of the language task at hand. For example, in reading, participants will read one word aloud, then complete some form of visual processing task. They will then read the next word aloud, followed by the visual processing task, and continue with this pattern. The same approach will be applied to naming and repetition. The non-language tasks will also vary; the participant will either have to produce some form of behavioural response (active) or not (passive). Participants will be audio recorded during the sessions, and responses transcribed manually. Transcriptions will be checked against the audio recording following the session. We will use within subjects statisitcal tests to identify whether there is a difference in accuracy across the different tasks.

An additional neuropsychological battery will be administered to examine the participants langauge and cogntive profile and enhance interpretation of the experimental results. This battery will consist of clinical and in-house language and executive (memory, reasoning, switching, updating etc.) tests.

Breaks will be planned within the sessions and participants will be reminded that they can stop at any time.

2.3 Location

Where will the project take place? Participants own homes

If the project is to take place in schools, please confirm that you have informed the SREC (*PCLSethics@reading.ac.uk*): ☐

If you plan to do home visits for the data collection, you need to perform a risk assessment and provide information about what safety measures you will take: Click here to enter text.

2.4 Funding

Is the research supported by funding from a research council or other external sources (e.g. charities, business)? Yes

If "Yes", please give details: Junior Training Fellowship from The Stroke Association awarded to Emma Pilkington.

Please note that some Research Councils or other external funding sources may require that the project is reviewed by the University Research Ethics Committee. If this is the case, then the project should be submitted to the University Committee. This does not apply to postgraduate activity funded by Research Councils.

2.5 Ethical Issues

Could this research lead to any risk of harm or distress to the participants? Please explain why this is necessary and how any risk will be managed.

Informed Consent: Individuals with Jaron aphasia for the most part have co-occuring impairments of language comprehension. Only individuals have can provide informed consent will be recruited to the study. Information will be provided using a total communication approach which enhances comprehension with all individuals with aphasia. Emma Pilkington is a specialist speech and language therapist with significant experience in working with individuals with jargon aphasia and a range of cognitive capacities. Emma is sufficiently experienced to make judgments regarding informed consent. It is the applicants experience that almost all individuals are able to provide informed consent following the relevant adaptations to communication strategies.

Neuropsychological Testing: People with aphasia may become frustrated or distressed at failure on neuropsychological tests or session tasks. Tests and sessions are designed to include regular breaks for participants. Individuals who present with continued frustration or distress will be reminded that they may discontinue the research at any time. It is the applicants experience that individuals' experience of research is more positive than negative, even following difficult testing conditions. The experimental and neuropsychological battery will be structured to intermix relatively more difficult and easier tasks as much as possible.

Communicating with individuals with Jaron Aphasia: Because of the nature of the condition, individuals with Jaron aphasia have more difficulties in expressing their needs than other indivdiuals. Emma Pilkington is experienced at working with people who have Jargon aphasia and has skills in interpreting non-verbal signs of distress. If participants are displaying such signs they will be reminded that they can stop at any time and that participation in the study is voluntary. Emma has experience in using multimodal strategies to facilitate the communication of individuals with Jargon aphasia.

Overall this study has low ethical risks.

2.6 Deception

Will the research involve any element of intentional deception at any stage (i.e. providing false or misleading information about the study)? No

If "Yes", please justify why: Click here to enter text.

Please note you must append a description of the debriefing procedure if the study involves deception.

2.7 Payment

Will you be paying your participants for their involvement in the study? No

If "Yes", please justify the amount paid: Click here to enter text.

Please note that excessive payment may be considered coercive and therefore unethical. Travel expenses need not to be declared.

2.8 Data Protection, Confidentiality, Disposal of Data

What steps will be taken to ensure participant confidentiality? How will the data be stored? When will the data be destroyed?

Please note that consent forms have to be kept for 5 years after the end of the study. There is no requirement for data, such as paper questionnaires, to be kept for 5 years.

This study will generate paper and electronic copies of participant performance on both neuropsychological tests and session activities. Both audio and paper records of performance will be taken during the session. These will then be transferred into electronic format where necessary, which will be stored on University of Reading (UoR) computers (desktop and laptop) and external hard drives. All paper and electronic data will be coded and anonymised. This will be stored in a locked cupboard in UoR restricted access office space. Both neuropsychological paper based forms and consent forms will be stored for five years. Emma Pilkington will be responsible for data storage.

Personally identifiable participant information will only be in the participants research file which will be stored in a locked cupboard in the School of Psychology and Clinical Language Sciences offices with restricted access. Participants who have consented to the current study only will have their details destroyed post five years of data collection. Participants who consent to being contacted about future studies will have their details stored on the Clinical Language Sciences research database.

Personally identifiable participant contact information will be accessible to Holly Robson, Emma Pilkington and any employed research assistants that are employed to carry out project work under the supervision of Holly Robson.

For data analysis, publications and dissemination of findings, only anonymised data (participant code) will be used. Anonymised data may be shared temporarily with research assistants, academics, post graduate and undergraduate students for use in future research studies. The data will be stored and managed by Holly Robson and Emma Pilkington.

Consent forms will be stored for a minimum of 5 years. Neuropsychological data will be stored indefinately for use in future research projects.

2.9 Consent

Please describe the process by which participants will be informed about the nature of the study and the process by which you will obtain consent.

Please note that a copy of consent forms and information letters for all participants must be appended to this application.

Written consent will be obtained for all participants. Consent will be taken by Emma Pilkington. Participants will only be able to take part in the study once informed consent has been given. If the participant's capacity to provide informed consent is in doubt, then Emma Pilkington, A speech and Language Therapist, will assess capacity. Consent will be gained for researchers to contact the participants GP if deemed necessary.

Information forms will be adapted for individuals with aphasia and comprehension impairments. In addition, Emma Pilkington will explain study information to potential participants face to face using adapted "total communication" methods. These methods include the use of written langauge, pictures, gesture, demonstration etc. to ensure comprehension. Emma Pilkington is highly experienced in working with individuals with reduced comprehension and the above techniques. Information sheets for the participant's friends and relatives will be available and provided on request from the participant. Participants will be given time to consider their involvement in the project and time to discuss their involvement with relatives and friends.

Participants will be identified from stroke clubs, the clinical language sciences adult research database and from previous participants who have expressed an interest in continuing with research.

Written consent will be obtained from participants immediately prior to data collection.

Please see attached documents

1. consent form

2. written information sheet
3. adapted information sheet.

SECTION 3: PARTICIPANT DETAILS

3.1 Sample Size

How many participants do you plan to recruit? Please provide a brief justification for this number.

We will aim to recruit up to 15 individuals with jargon aphasia, however it is likely that this number will be somewhat smaller due to the rarity of the condition and the nature of the impairment making it challenging to identify and contact individuals. 10 participants is a realistic target.

It is not possible to provide a power calculation at this point in time. As noted in the introduction, previous research has, for the most part, involved single case studies. However, the severity of the condition is such that effect sizes are considerable.

3.2 Sample Characterisation

Will the research involve children or vulnerable adults (e.g. adults with mental health or neurological conditions)? Yes

If "Yes", how will you ensure these participants fully understand the study and the nature of their involvement in it and freely consent to participate?

This research will involve adults with acquired communication impairments following stroke. These participants will be living in the community and under the care of their GP and possibly on a speech and language therapy caseload. As outlined in the procedure section, participants will be recruited from stroke clubs and research databases. All materials used to inform potential participants about the research will be in aphasia friendly format as described in the consent section (please see attached documents) Participants will not be recruited directly from the NHS sources and this study will require no direct access to medical notes.

Please append letters and, if relevant, consent forms, for parents, guardians or carers. Please note: information letters must be supplied for all participants wherever possible, including children. Written consent should be obtained from children wherever possible in addition to that required from parents.

3.3 Sample Age

Will your research involve children under the age of 18 years? No

Will your research involve children under the age of 5 years? No

3.4 NHS and Social Services Involvement

Will your research involve NHS patients or Clients of Social Services? No

Please note that if your research involves NHS patients or Clients of Social Services your application will have to be reviewed by the University Research Ethics Committee and by an NHS research ethics committee.

3.5 Recruitment

Please describe the recruitment process and append any public advertising if used *(advertisements on the Research Panels do not need to be appended)*.

Stroke participants will be recruited from the existing clinical language sciences database at the University of Reading, stroke clubs and from participant registries at collaborating sites. From these sites, 10 potential participants who have expressed interest in taking part in further research have already been identified and are known to the research team. Participants from the database will in the first instance be contacted by Emma Pilkington, who will explain that there is a new study at the University of Reading. If participants are interested, they will be visited at home and further explanation about the research project will be given in aphasia friendly format (as described in the consent section). Holly Robson, Emma Pilkington or other trained researchers will visit stroke clubs with the permission of the stroke club co-ordinator. The research will be explained in aphasia friendly format. If participants are suitable and express an interest in the research project, further explanation will be provided using aphasia adapted information sheets and total communication approach. Interested participants will be given the option to consent for their details to be taken and contacted in due course about participating in the research study. A further visit will then be arranged to explain the research again and take consent to participate if appropriate.

Inclusion criteria:

Single stroke (previous TIAs would not lead to exclusion)

Pre morbid fluent English

Fluent speech

Impaired spoken word production.

Exclusion criteria:

Other significant neurological history

History of drug/alcohol abuse

IMPORTANT NOTES

1. *The Principal Investigator must complete the Checklist below to ensure that all the relevant steps have been taken and all the appropriate documentation has been appended*
2. *If you expect that your application will need to be reviewed by the University Research Ethics Committee you must also complete the Project Submission Form*
3. *For template consent forms and information sheets see the document "example consent forms and information letters"*
4. *If the research is being carried out by undergraduates for their Final Year project, a special consent form must be used. This is shown in the "example consent forms and information letters" document*

CHECKLIST

This form must be completed by the Principal Investigator.
This form should be used if you submit your application to the School Research Ethics Committee
Please tick to confirm that the following information has been included and is correct. Indicate (N/A) if not applicable:

Information Sheet

Is on headed notepaper and the information in the header is up-to-date	☐	
Includes Investigator's name and email / telephone number	☐	
Includes Supervisor's name and email / telephone number	☐	
Does not include student mobile phones / personal e-mails	☐	
Includes the title of the study	☐	
Includes the aims of the study	☐	
Includes information about what the participants will be asked to do	☐	
Statement that participation is voluntary	☐	
Statement that participants are free to withdraw their co-operation	☐	
Reference to the ethical process using the sentence: *'This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.'*	☐	
Reference to Disclosure using the following sentence: *'All investigators on this project have had criminal records checks and have been approved by the School to work with children.'*	☐	N/A ☐
Reference to confidentiality, storage and disposal of personal information collected. Note, consent forms have to be kept for 5 years	☐	

Consent Form(s)

Please note that if researchers are undergraduates, you must use the "Undergraduate Project Consent Form" in Blackboard, and include researcher names	☐	

Other Relevant Material

Questionnaires	☐	N/A ☐
Interviews	☐	N/A ☐
Letters	☐	N/A ☐
Other (please specify)	☐	N/A ☐
Click here to enter text.		
Expected duration of the project (months)		Click here to enter text.

PRINCIPAL INVESTIGATOR

Name: Click here to enter text.

[redacted]

(Signed, Principal Investigator)

19-May-2016
Date

8.3 ***Appendix 3***

Study information sheet for Chapters 4 and 5

School of Psychology and Clinical
Language Sciences

Research Study

Jargon Busting: The cognitive and neurobiological mechanisms underpinning jargon aphasia and perseveration

Participant Information Sheet

Researcher:

Emma Pilkington

Clinical Language Sciences

University of Reading

Email: e.c.pilkington@pgr.reading.ac.uk

Supervisor:

Dr. Holly Robson

Clinical Language Sciences

University of Reading

RG6 6AL

Tel: [redacted]

Email: h.v.robson@reading.ac.uk

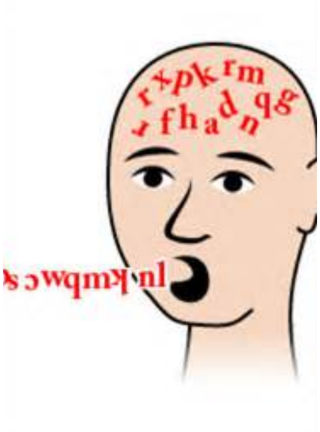
You are being **invited to take part in a research study** at the University of Reading.

This is **information about the study**.

Please take time to **think about** whether you would like to **take part**.

<u>What is the study about?</u>

After a **brain injury** people can have **problems producing words.**

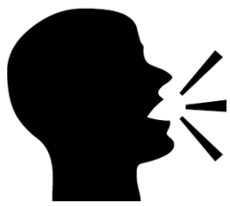


Some people say the **same**
words or sounds over and **over again**.

We do not fully understand **why** this happens.

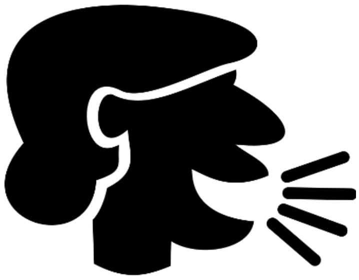
This study will **investigate what** things **affect spoken word production.**

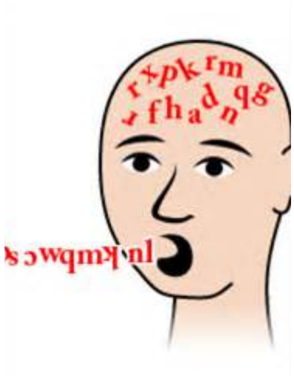
It involves **reading, repeating and naming** words and pictures.



We will use **lots of different words**.

We want to know **if some are easier than others**.





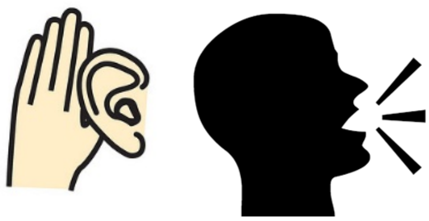
<u>What will I have to do?</u>

You will do some **speaking and listening tests**.

Then you will do tasks of **reading, repeating and picture naming**.

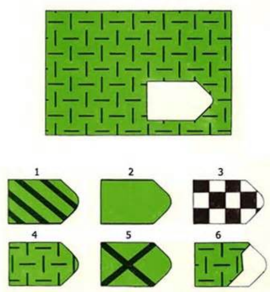
reading

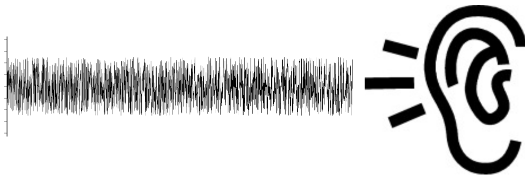
repeating



naming

Sometimes you might do **other tasks** in between words. These will not be speaking tasks.





<u>Do I have to take part?</u>

No. This study is **voluntary. You do not have to take part.**

<u>How long will it take?</u>

Each session will last around **1 hour**.

There will be **10** sessions.

<u>What if I don't like it?</u>

If you don't like being part of the study **you can stop**.

You **do not need** to give **a reason** to stop.

You can **stop at any time.**

<u>What are the burdens?</u>

Some tasks may be **harder** than others

This may be **frustrating at times**

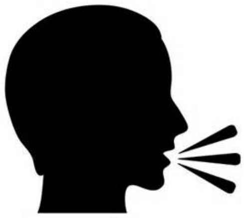
We can **stop or take a break whenever you want to**

<u>Where will it happen?</u>

It can take place at **your home** or at the **university**

<u>Will I be recorded?</u>

If **you agree**, we will **record** your **voice.**



Your details will remain **confidential**

This is **research**

This is **not** speech and language **therapy.**

If you would like to **take part**, we will ask you to **sign a consent form**.

If you have **any questions please ask**. You can **contact Holly** Robson on [redacted]**, or Emma on** **e.c.pilkington@pgr.reading.ac.uk**

8.4 ***Appendix 4***

Participant consent form for chapters 4 and 5.

School of Psychology and Clinical Language Sciences

Jargon Busting: The cognitive and neurobiological mechanisms underpinning jargon aphasia and perseveration

<u>Consent form</u>

I have **read** and **understood** the **information sheet** ☐

I have had the opportunity **to ask questions** ☐

I understand **I can withdraw from the study** without a reason ☐

I agree for some of the tests and sessions to be **audio recorded** ☐

I agree to **take part in the study** ☐

Signature: ______________________________ Date:______________

Participant
Name: ____________________________

Researcher
Name: ____________________________ Signature: _______________________________ Date: _______________

8.5 *Appendix 5*

Ethics approval note for chapters 4 and 5.

2016-064-HR - Jargon Busting: The cognitive and neurobiological mechanisms underpinning Jargon Aphasia and Perseveration – Emma Pilkington and Holly Robson.

9th June 2016

In my opinion, this study meets the requirements for ethical approval, and I am happy for it to proceed

John Harris

8.6 *Appendix 6*

Chapter 4 target word sets presented in alphabetical order

Repetition		**Reading**	
High	***Low***	***High***	***Low***
apartment	abode	animal	analogy
arm	acre	avenue	audit
audience	ally	band	border
bag	altitude	bridge	clash
building	anecdote	candidate	compression
butter	annex	cellar	crush
camp	aurora	chain	cult
car	beau	champion	debut
cattle	betrayal	chapel	defence
clay	bid	clothes	defiance
coffee	blessing	coach	despair
column	boast	core	dirge
display	brawl	country	enigma
drink	circuit	customer	flutter
drug	continent	detective	foe
executive	cunning	dive	fortune
filling	curse	driver	franchise
flash	deceit	earth	frenzy
gallery	denial	edge	fury
golf	dislocation	entrance	grievance
graduate	dismissal	forest	gush
grip	etiquette	ground	impediment
hall	expanse	hill	incline
professor	exterior	hotel	inhibition
human	flyer	industry	irritation
lift	forfeit	lunch	jerk
liquid	fraud	market	lunge
magazine	genius	material	margin
metal	gore	money	misery
monument	greed	mud	oath
motor	gulf	muscle	omen
music	haste	ocean	pact
newspaper	insight	painting	peep
novel	irony	paper	pioneer
partner	jolt	park	precaution
pattern	levity	penny	rebel
planet	loyalty	picture	receipt
pocket	maker	platform	regency
pool	marvel	pond	retreat
porch	mortal	quarter	rhyme

property	raid	radio	scorn
record	realm	rain	sedative
room	reprisal	register	sequel
sand	revenge	rifle	shrug
saw	rogue	salary	siege
shadow	saga	salt	sorrow
skirt	shaker	secretary	stride
smile	sneer	sheet	strut
soil	snort	shirt	tally
soldier	spree	silver	thaw
student	thinker	smoke	theft
sun	treaty	staff	tip
tape	tremor	station	torment
teacher	tumble	supper	trance
uniform	utterance	university	trim
valley	verity	water	tuck
victim	vigil	winter	turner
village	vow	witness	venture
weapon	whack	wound	watt
wedding	whirl	writing	wiggle

8.7 *Appendix 7*

Mean and standard deviation (in parentheses) statistics of psycholinguistic values for Chapter 4 target word sets.

	Repetition		**Reading**	
	High	***Low***	***High***	***Low***
KF frequency	82.82 (78.53)	7.60 (6.74)	86.33 (80.04)	7.62 (6.60)
Celex frequency	73.947 (87.39)	6.34 (5.80)	79.94 (88.60)	8.76 (12.3)
Log frequency	1.71 (0.36)	0.73 (0.36)	1.72 (0.40)	0.81 (0.38)
Concreteness	549.67 (47.53)	366.60 (76.53)	554.03 (51.03)	365.67 (61.61)
Familiarity	550.83 (52.83)	414.08 (58.47)	556.97 (52.45)	422.88 (58.8)
Imageability	561.55(42.96)	408.17 (61.63)	563.08 (48.75)	408.28 (65.14)
Phoneme number	4.93 (1.74)	4.93 (1.76)	5.00 (1.74)	4.98 (1.81)
Syllable number	1.82 (0.75)	1.93 (0.82)	1.88 (0.83)	1.87 (0.89)
Letter number	5.77 (1.70)	5.93 (1.66)	5.97 (1.56)	5.98 (1.87)
Phonological neighbourhood density	7.5 (8.79)	6.13 (8.62)	8.18 (9.78)	6.2 (8.27)
Orthographic neighbourhood density	3.90 (5.04)	2.47 (3.09)	3.04 (4.47)	2.67 (3.43)
Phoneme position frequency	0.26 (0.11)	0.26 (0.13)	0.27 (0.13)	0.25 (0.11)
Biphone position frequency	0.021 (0.02)	0.02 (0.02)	0.021 (0.02)	0.02 (0.02)
Bigram position frequency	1685.03 (893.19)	1654.32 (1041.67)	1931.03 (936.26)	1645.25 (1002.95)

8.8 *Appendix 8*

Number of correct, nonword and other responses types observed on tasks of single word repetition and reading for each participant in Chapter 4.

		Repetition										Reading									
		Participant code																			
Response type	Lexical availability	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Correct	Low	43	-	2	3	0	17	3	0	0	0	57	27	-	6	0	0	0	0	0	0
	High	51	-	9	26	3	22	11	0	0	0	58	39	-	20	2	2	0	1	1	0
Nonword	Low	8	-	35	51	53	37	45	56	60	58	3	27	-	44	44	51	56	59	60	59
	High	4	-	25	27	27	23	43	59	52	54	1	17	-	29	37	54	60	49	53	59
Formal	Low	6	-	5	4	2	4	8	1	0	0	0	6	-	4	11	2	1	1	0	0
	High	5	-	5	4	8	11	5	1	2	1	1	4	-	7	14	1	0	5	3	0
Unrelated	Low	2	-	10	1	5	1	3	3	0	1	0	0	-	4	5	7	3	0	0	1
	High	0	-	6	3	21	1	0	0	6	4	0	0	-	3	7	3	0	4	3	1
Semantic	Low	0	-	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0
	High	0	-	0	0	1	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0
Mixed	Low	1	-	0	1	0	0	0	0	0	0	0	0	-	2	0	0	0	0	0	0
	High	0	-	0	0	0	2	0	0	0	0	0	0	-	1	0	0	0	1	0	0
Non-response	Low	0	-	8	0	0	1	1	0	0	1	0	0	-	0	0	0	0	0	0	0
	High	0	-	15	0	0	0	1	0	0	1	0	0	-	0	0	0	0	0	0	0

Note: hyphen indicates missing data.

8.9 *Appendix 9*

Effect of lexicality on production performance for participants in chapter 5.

A factorial repeated measures ANOVA was used to determine whether the trial format (Standard, Pause, Passive, Active) and lexical difficulty (high availability and low availability) influenced the severity of Jargon production, indexed by the number of nonword errors produced. Results demonstrated no effect of lexicality (F(1,7) = 3.183, *p* = .118, ηp2 = .313), no effect of trial format (F(3,21) = .574, *p* = .638, ηp^2 = .076) and no interaction (F(3,21) = .642 p = .596, ηp2 = .084; see Figure 4). In the absence of lexical effects, the word sets were collapsed to create a single test word set of 120 items.

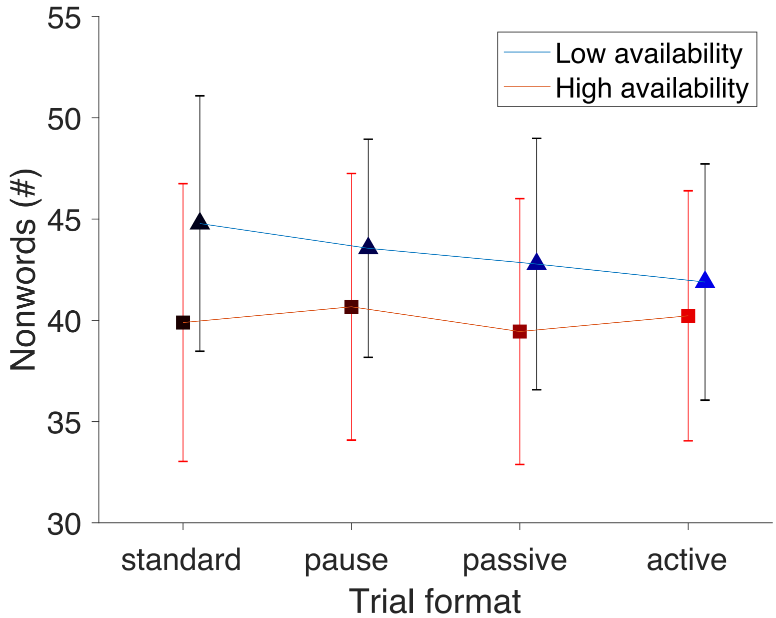


Figure 8.1: Mean number of nonwords produced across the different trial types for the hard and easy word conditions. Error bars indicate +- 1 standard error

8.10 ***Appendix 10***

Phonological Accuracy (POI) statistics for nonwords produced on single word tasks in chapter 3

	Phonological Overlap Index		
	Repetition	Reading	Naming
p1	0.68	0.62	0.45
p2	0.50	0.51	0.42
p3	0.61	0.58	0.51
p4	0.59	0.44	0.25
p5	0.35	0.53	0.45
p6	0.59	0.55	0.51
p7	0.49	0.53	0.40
p8	0.45	0.40	0.46
p9	0.37	0.32	0.25
p10	0.27	0.52	0.23