UNDERSTANDING WORD RETRIEVAL IN LOGOPENIC VARIANT PRIMARY PROGRESSIVE APHASIA: EXAMINATION OF PSYCHOLINGUISTIC PROPERTIES ACROSS TASKS

by

Fatima Jebahi

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF SPEECH, LANGUAGE, AND HEARING SCIENCES

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

2026

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation prepared by *Fatima Jebahi,* titled *Understanding Word Retrieval in Logopenic Variant Primary Progressive Aphasia: Examination of Psycholinguistic Properties Across Tasks* and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Aneta Kielar
_____ Date: 07/30/2026
Aneta Kielar

Elena Plante
Elena Plante (Jul 31, 2026 17:02:52 PDT)
_____ Date: 07/31/2026
Elena Plante

Leah L Kapa
_____ Date: 08/03/2026
Leah Kapa

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Aneta Kielar
_____ Date: 07/30/2026
Aneta Kielar
Dissertation Committee Chair
Speech, Language and Hearing Sciences

ACKNOWLEDGEMENTS

This dissertation, and the degree that comes with it, would not have been possible without the support, mentorship, and encouragement I have received along the way.

I would like to express my deepest gratitude to my dissertation committee members. I thank my mentor, Dr. Aneta Kielar, for guiding me throughout both my dissertation and doctoral program with generosity, patience, and encouragement. Her mentorship, especially through our many discussions on research design and application, has shaped me into a more rigorous rescarcher. I am grateful for the many opportunitics she has offered me and for her support over the years. I also thank Dr. Elena Plante for her guidance, discussions on theoretical and methodological considerations, and for encouraging me to always ask deeper questions. I thank Dr. Leah Kapa for her thoughtful feedback on my work and for her support throughout this process.

I have been fortunate to be surrounded by colleagues whose friendship and intellect made this journey not only productive but also joyful. I thank Dr. Katlyn Nickels, soon-to-be Dr. Rebecca (Becky) Burton, Dr. Sarah Lynn Neiling, Dr. Alyssa Sachs, and Dr. Heidi Mettler for creating an environment filled with uplifting and shared purpose. I am grateful for my friends back home, Zahraa Shihimi, Haibat Darwish, and Dr. Mariam El-Amin, for their continued friendship and for cheering me on from afar.

Thank you to the incredible lab members who supported this dissertation behind the scenes. Specifically, I thank Isabella Lopez, Cecilia Silva, and Noah Frazier, for their assistance in data organization and coding. Their attention to detail and commitment to the studies of this dissertation were invaluable. I am also thankful to the participants who took part in this research for their time

and willingness to share their experiences. I have learned so much from them, not only as a researcher but as a human being.

I thank my cousin and best friend, Ghadir Bazzoun, for being the person I can always turn to, for listening to my endless voice notes, and for standing by me through every season. I am lucky to have her in my life.

I am endlessly grateful to my family. I thank my parents, Hassan and Inaam Jebahi, for believing in me, for encouraging me to pursue my dreams, and for the countless sacrifices they made so I could follow this path. I thank my siblings: Diana, for always offering a shoulder for me to lean on, Ali, for being a source of lightness, and Yehya, for his humor that never fails to lift my spirits.

Finally, I am most thankful for my husband and life partner, Mahdi. His love, support, and presence have been my anchor. Every step of this journey has been lighter because he walked it with me, even when from a distance.

LAND ACKNOWLEDGMENT

We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT[1]

Among the core features of the logopenic variant of primary progressive aphasia (lvPPA), word retrieval impairment represents a defining and salient symptom. This deficit is thought to stem primarily from impairments in phonological encoding, though individuals with lvPPA may also demonstrate semantic processing impairments, albeit to a lesser degree. Word retrieval difficulties manifest across language contexts, ranging from single word naming to discourse, and are influenced by the integrity of the language system and by intrinsic characteristics of words themselves. These characteristics, often referred to as psycholinguistic properties, influence the ease of lexical access and may explain patterns of preserved and impaired naming in lvPPA. However, little is known about how these properties influence word retrieval in this population. This dissertation addressed this gap by examining the effects of psycholinguistic properties on lexical retrieval across three tasks that vary in their cognitive and linguistic demands: confrontation naming, verbal fluency, and narrative discourse.

In the first study, naming accuracy was assessed in 14 individuals with lvPPA using the Boston Naming Test. Eight psycholinguistic properties, including frequency, familiarity, Age of acquisition (AoA), word length, phonological neighborhood density (PND), SND, arousal, and valence were examined through regression analyses. AoA emerged as the strongest predictor of naming accuracy, with earlier-acquired words named more accurately.

[1] This dissertation contains material adapted from:
Jebahi, F., Nickels, K. V., & Kielar, A. (2024a). Predicting confrontation naming in the logopenic variant of primary progressive aphasia. *Aphasiology*, *38*(4), 635-666. https://doi.org/10.1080/02687038.2023.2221998
Jebahi, F., Nickels, K. V., & Kielar, A. (2024b). Patterns of performance on the animal fluency task in logopenic variant of primary progressive aphasia: A reflection of phonological and semantic skills. *Journal of Communication Disorders*, *108*, 106405. https://doi.org/10.1016/j.jcomdis.2024.106405

In the second study, 15 participants with lvPPA and 20 controls completed an animal fluency task. Individuals with lvPPA produced fewer correct responses and words with earlier AoA. Phonological ability partially mediated the relationship between AoA and word generation, such that stronger phonological skills supported retrieval of later-acquired words and enhanced overall fluency. Both phonological and semantic abilities predicted overall fluency performance and the psycholinguistic properties of generated words. Stronger abilities in these domains were linked to words lower in frequency, acquired later in life, and with fewer semantic neighbors. Additionally, greater semantic ability was associated with producing less familiar and less arousing words.

In the third study, discourse samples were elicited from 20 individuals with lvPPA and 19 neurotypical controls using picture description and storytelling tasks. Individuals with lvPPA showed systematic lexical biases toward words that were easier to access, including words higher in frequency and familiarity, shorter in length, embedded in varied phonological and semantic neighborhoods, and lower in imageability and arousal. These effects were more pronounced for verbs than nouns, reflecting compensatory lexical selection strategies. Across both tasks, AoA predicted discourse informativeness, with later-acquired words associated with greater communicative success.

Together, the findings of the studies of this dissertation show AoA as a central psycholinguistic determinant of lexical retrieval across tasks in lvPPA. Earlier-acquired words maximize accessibility in single-word constrained tasks, whereas later-acquired words enhance informativeness in discourse. The results also show that task demands modulate which

psycholinguistic properties drive lexical accessibility, such that the language system in lvPPA reweights lexical features to optimize communication under phonological and semantic constraint.

CHAPTER 1: GENERAL INTRODUCTION

Primary Progressive Aphasia

Primary progressive aphasia (PPA) refers to a group of neurodegenerative syndromes characterized by a progressive and predominant deterioration of language abilities, which occurs due to gradual atrophy of the language network in the left hemisphere (Gorno-Tempini et al., 2011). This deterioration is driven by progressive neurodegeneration associated with underlying proteinopathies, most commonly frontotemporal lobar degeneration (FTLD; tau or TDP-43 pathology) or Alzheimer's disease pathology, depending on the PPA variant (Mesulam et al., 2014). Unlike other neurodegenerative disorders such as Alzheimer's disease or behavioral variant frontotemporal dementia, PPA is distinguished by language deterioration with relative sparing of other cognitive domains during the early stages of the syndrome (Mesulam, 1982). Therefore, the diagnosis of PPA relies on the presence of language impairment as the primary clinical deficit, and on the absence of generalized cognitive impairments in the initial phases. Clinically, this is confirmed through a process of diagnostic inclusion and exclusion involving both verbal and non-verbal cognitive assessments.

PPA was first described by Mesulam in 1982, who reported six cases of "slowly progressive aphasia without generalized dementia", all of whom demonstrated progressive language deterioration over a period of 5 to 11 years, in the relative absence of other cognitive or behavioral impairments. This foundational work established PPA as a distinct dementia syndrome and laid the groundwork for future research into its clinical and neuroanatomical characteristics. Since then, an expanding body of research has sought to characterize the clinical profiles, progression patterns, and underlying neuroanatomical atrophy patterns associated with PPA (e.g., Grossman et al., 1996; Hodges et al., 1992). Despite this growing literature, PPA remains a relatively rare condition, with prevalence estimates ranging from approximately 3 to 7 cases per

100,000 individuals (Coyle-Gilchrist et al., 2016; Grossman, 2010). This low incidence presents a significant challenge for research, as it limits the feasibility of recruiting large, homogeneous samples at a single site or within a narrow time frame. At the same time, data obtained from PPA individuals are valuable to enhance the understanding of neural correlates of langauge and its breakdown.

Over time, it became evident that PPA is not a unitary disorder, but a heterogeneous clinical group of syndromes with different subtypes. The first effort to systematically classify these subtypes was made by Neary et al. (1998), who proposed criteria aimed at characterizing language profiles commonly associated with FTLD. Two variants were introduced: (1) semantic dementia, which was defined by severe impairments in word comprehension and naming due to degradation of conceptual knowledge (often accompanied by object recognition deficits), and (2) progressive nonfluent aphasia, characterized by impaired speech fluency, motor speech deficits, and agrammatism, due to deficits in speech production and syntactic processing.

However, the Neary et al. (1998) criteria had limitations. First, the criteria did not account for patients with prominent lexical retrieval difficulties and preserved grammar and comprehension, which comprised a considerable group of unclassified individuals (Grossman & Ash, 2004). Second, the inclusion of individuals with object recognition deficits in the semantic dementia category combined language-based deficits with broader perceptual impairments and did not fit the core premises of PPA (Mesulam et al., 2003). Third, the criteria were restricted to patients with FTLD pathology and excluded individuals with PPA caused by other neuropathologies (Mesulam et al., 2008).

In response to these issues, a multidisciplinary group of experts established revised classification guidelines (Gorno-Tempini et al., 2011). These international consensus criteria

redefined the diagnostic framework and provided a standardized approach that remains the basis of current clinical and research practices. The revised guidelines classify PPA into three main variants based on clinical features and associated patterns of brain atrophy: the semantic variant (svPPA), the nonfluent/agrammatic variant (nfvPPA), and the logopenic variant (lvPPA).

Semantic Variant of Primary Progressive Aphasia

SvPPA is characterized by a progressive loss of semantic knowledge, resulting in naming difficulties and impaired single-word comprehension. Clinically, individuals with svPPA often present with fluent yet empty speech as well as significant naming impairments, particularly for low-frequency or abstract nouns (Bird et al., 2000; Gorno-Tempini et al., 2011; Lambon Ralph et al., 1998). These naming impairments are not reduced if individuals are provided with phonemic cues, which highlights the semantic nature of the deficit. Additionally, individuals with svPPA demonstrate impaired comprehension of single words. These language difficulties arise from a deterioration of lexical-semantic system where conceptual knowledge that underpins understanding of word meanings is stored (Minsky, 1975).

From a neuroanatomical perspective, svPPA is associated with prominent atrophy of the anterior and inferior regions of the left temporal lobe (Agosta et al., 2010; Mummery et al., 1999; Rosen et al., 2002; Snowden et al., 2018). This region is a critical hub of the ventral language pathway, which is involved in mapping word forms to conceptual representations (Hickok & Poeppel, 2004; Kielar et al., 2022). As the disease progresses, atrophy extends to the contralateral right temporal lobe and into posterior temporal areas, which gives rise to broader deficits in social cognition, nonverbal semantic processing, and behavioral regulation (de la Sablonnière et al., 2021).

Nonfluent/Agrammatic Variant Primary Progressive Aphasia

NfvPPA is characterized by effortful, halting speech with disrupted grammar and/or apraxia of speech. Individuals with nfvPPA typically maintain unimpaired word comprehension in the early stages but show impairments in the understanding complex sentences as well as in production and syntactic structuring of language (Charles et al., 2014; Gorno-Tempini et al., 2011). Speech in nfvPPA is marked by reduced fluency, speech sound distortions, and simplified or fragmented sentence construction (Grossman, 2012). Additionally, agrammatism is often evident and includes omissions or substitutions of function words and morphemes (Montembeault et al., 2018; Thompson et al., 2013, Thompson & Mack, 2014). For example, an individual may say "dog fetch ball" instead of "the dog played fetch with the ball". In some cases, speech is also affected by apraxia of speech, a motor planning deficit that results in distorted prosody, inconsistent articulation errors, and articulatory groping (Croot et al., 2012). Although both agrammatism and apraxia of speech can occur independently, they frequently co-occur in nfvPPA (Illán-Gala et al., 2024).

Neuroanatomically, nfvPPA is associated with atrophy in the left posterior inferior frontal gyrus (including Broca's area), the anterior insula, and adjacent premotor regions (Gorno-Tempini et al., 2004, 2011; Grossman, 2012; Mandelli et al., 2016; Rogalski et al., 2011). Degeneration in these regions disrupts both the dorsal language pathway and frontal motor circuits that support grammatical construction and speech articulation (Catani et al., 2003; Mandelli et al., 2014).

Logopenic Variant Primary Progressive Aphasia

LvPPA is the most recently recognized subtype of PPA and is often regarded as the most heterogeneous, with individuals presenting a wide spectrum of symptoms and disease progression (Gorno-Tempini et al., 2011; Leyton et al., 2015). This variant was initially characterized by

Gorno-Tempini et al. (2004) and subsequently refined in later work (Gorno-Tempini et al., 2008; Gorno-Tempini et al., 2011). The hallmark features of lvPPA include word retrieval difficulties and impaired repetition, while grammar, motor speech, and single-word comprehension are relatively spared in early stages (Gorno-Tempini et al., 2011). Deficits in phonological processing and verbal working memory are central to this variant, which contribute to the observed impairments.

Although individuals with lvPPA demonstrate relatively preserved comprehension of single words, they may struggle with understanding complex or lengthy sentences, a difficulty attributed to reduced verbal working memory capacity (Mesulam et al., 2014). This deficit is also evident in repetition tasks, particularly as phrase and sentence length increases (Gorno-Tempini et al., 2011; Kamath et al., 2020; Mesulam et al., 2014). Individuals with lvPPA often employ semantic strategies during these tasks, such as paraphrasing (e.g., “the dog chased the ball” for “the friendly dog played fetch with the colorful ball”), to compensate for their phonological impairnment and verbal working memory deficits (Gorno-Tempini et al., 2011).

At the discourse level, speech tends to be slow but grammatically correct, with word-finding pauses, self-corrections, circumlocutions, hesitations, and phonological errors (Ash et al., 2009; Wilson et al., 2010). Their discourse is also characterized by an increased use of pronouns and verbs, fewer well-formed sentences, and frequent rewordings (Lavoie et al., 2021; Wilson et al., 2010). These challenges are mainly due to lexical retrieval challenges, where individuals often struggle to retrieve content words, particularly nouns, which in turn leads to reduced informativeness (Gallée et al., 2021).

Neuroimaging studies consistently implicate dorsal posterior perisylvian regions, including the left posterior superior and middle temporal gyri, the angular gyrus, and the supramarginal gyrus

(Brambati et al., 2009; Giannini et al., 2017; Madhavan et al., 2013; Rogalski et al., 2011). These regions are involved in phonological processing and lexical retrieval, consistent with the behavioral profile of the variant. As the disease progresses, cortical atrophy may spread to adjacent temporal areas and the contralateral hemisphere (Mesulam et al., 2014) and give rise to broader cognitive and language impairments.

Word Retrieval Impairment in Logopenic Variant Primary Progressive Aphasia

Word retrieval, the ability to access and select appropriate words from the mental lexicon, is a foundational component of speech production. This process enables individuals to transform thoughts into spoken language by selecting lexical representations that match their intended meaning and retrieving the corresponding phonological forms. Efficient lexical access depends on cognitive skills, including semantic and phonological abilities, as well as psycholinguistic factors such as the inherent properties of words (e.g., frequency, familiarity, age of acquisition (AoA), etc…). In individuals with language disorders, particularly those with lvPPA, word retrieval impairment is commonly the first reported symptom and is associated with significant communication difficulties (Gorno-Tempini et al., 2011).

To understand the mechanisms underlying word retrieval and how they break down in lvPPA, it is important to consider the cognitive models that aim to explain these mechanisms. Two prominent frameworks: (1) the Levelt's Model of Lexical Access (Levelt et al., 1999), and (2) Dell's Interactive Activation Model (Dell et al., 1997), have shaped much of what is known about the process of word production and lexical access.

Levelt's Model of Lexical Access (Levelt et al., 1999) describes word production as a sequential, multi-stage process that begins with conceptual preparation, where a preverbal message is formed, followed by lexical selection, phonological encoding, and finally articulation. An important feature of this model is the two-step process of lexical access, which includes: (1) lexical

selection, the retrieval of a word's semantic and syntactic properties (i.e., its lemma), without accessing its phonological form, and (2) phonological encoding, the retrieval and assembly of a word's phonological form for articulation. This distinction is important for understanding the types of word retrieval errors seen in clinical populations. For example, difficulty in lexical selection may result in semantic paraphasias (e.g., saying "dog" instead of "cat"), while errors in phonological encoding can be seen as phonological paraphasias (e.g., "cap" for "cat").

Dell's Interactive Activation Model (Dell et al., 1997) proposes a cascading and bidirectional flow of activation between semantic, lexical, and phonological levels. This interactive framework allows for feedback between processing levels and helps explain more complex speech errors such as mixed errors, where both semantic and phonological competitors influence word retrieval (e.g., saying "rat" for "cat"). This model accounts for the probabilistic nature of speech production and is particularly useful for explaining how multiple levels of linguistic processing may be simultaneously involved in the retrieval process (Dell et al., 1997; Rapp & Goldrick, 2000).

Both Levelt's (Levelt et al., 1999) and Dell's (Dell et al., 1997) models support the idea that lexical retrieval involves semantic and phonological abilities. The initial stage involves the activation and selection of an abstract lexical representation tied to meaning but not yet linked to sound. It is influenced by semantic features and subject to competition from semantically related words (Hameau et al., 2020). Factors such as familiarity and semantic neighborhood density (SND) also modulate the efficiency of this stage (Jescheniak & Levelt, 1994; Hameau et al., 2020). Neuroimaging studies implicate the left middle and inferior temporal gyri, regions involved in lexical-semantic processing, in this stage (Indefrey & Cutler, 2004). After the lemma is selected, the next stage is the retrieval of the phonological form of the word. This includes assembling the

phonological structure of the word and preparing it for articulation (Miozzo & Caramazza, 1997). Disruptions at this stage can result in phonological paraphasias or neologisms (Nickels, 2002). Brain regions associated with phonological encoding include the left superior temporal gyrus and Broca's area (Indefrey & Cutler, 2004).

Among the core features of lvPPA, word retrieval impairment represents a defining and salient symptom (Gorno-Tempini et al., 2011). Specifically, individuals with lvPPA exhibit word-finding pauses, circumlocutions, and phonological errors, even in otherwise grammatically intact speech (Gorno-Tempini et al., 2011; Wilson et al., 2010). These difficulties are thought to stem primarily from impairments in phonological encoding, though semantic processing may be impaired to a lesser degree (Mesulam et al., 2014; Kamath et al., 2020). These lexical retrieval deficits are evident in different naming tasks. For instance, in confrontation naming tasks, individuals with lvPPA may fail to retrieve the target word or produce phonological paraphasias instead (e.g., Gorno-Tempini et al., 2010). In verbal fluency tasks, they often retrieve fewer words and have longer pauses between responses (e.g., van den Berg et al., 2024) In discourse tasks, their speech is frequently interrupted by long pauses, rewordings, generic terms, and reduced informativeness (e.g., Ash et al., 2009; Wilson et al., 2010; Lavoie et al., 2021). These manifestations across tasks highlight the multidimensional nature of word retrieval difficulties in lvPPA and underscore the importance of examining lexical retrieval in different assessment contexts.

Difficulties with word retrieval in lvPPA influence broader aspects of communication and daily functioning. Everyday conversations become effortful and frustrating and affect person's confidence, mood, and social participation (Medina & Weintraub, 2007). Many individuals with lvPPA are aware of their declining communication abilities, which can lead to increased anxiety,

social withdrawal, diminished sense of self, and reduced quality of life (Gallée, 2023; Ruggero et al., 2019; Ruggero et al., 2023). Given its central role in communication and its broad impact on well-being, understanding word retrieval impairment in lvPPA is a primary target for many researchers and clinicians.

Psycholinguistic Properties and Word Retrieval

Not all words are equally vulnerable to retrieval difficulties. The ease or difficulty with which a word is retrieved depends on the integrity of the speaker's semantic and phonological systems, and also on inherent characteristics of the word itself. These characteristics, known as psycholinguistic properties, interact with cognitive processes during lexical access and influence whether a word is successfully retrieved or not. In the context of language disorders, including lvPPA, examining how these properties affect word retrieval can help explain patterns of preserved and impaired naming.

Psycholinguistic properties refer to measurable features of words that influence how they are processed, accessed, and retrieved from the mental lexicon. These properties shape the speed and accuracy of lexical access by modulating activation levels at various stages of word production, including semantic activation, lexical selection, and phonological encoding (Dell et al., 1997; Levelt et al., 1999). Research in both neurotypical and clinical populations has shown that these properties significantly affect naming performance (Lambon Ralph et al., 1998; Nickels & Howard, 1995), and that different clinical populations may show distinct patterns of effects from psycholinguistic properties (Lambon Ralph et al., 1998; Nickels & Howard, 1995). For example, Nickels and Howard (1995) found that AoA and word length were key predictors of naming in post-stroke aphasia, while Lambon Ralph et al. (1998) found that frequency and familiarity were more predictive svPPA. Commonly studied psycholinguistic properties that have shown influence

on word retrieval include frequency, familiarity, AoA, imageability, word length, phonological neighborhood density (PND), SND, arousal, and valence (Alario et al., 2004; Ellis & Lambon Ralph, 2000; Jurafsky, 2003).

Frequency

Frequency refers to how often a word occurs in a language and is typically derived from large corpora (Brysbaert & New, 2009). High-frequency words have been shown to be more readily retrieved than low-frequency words in picture naming tasks (Kittredge et al., 2008; Oldfield & Wingfield, 1965). This frequency effect is thought to arise from the stronger and more readily activated representations of high-frequency words in the mental lexicon. Neuroimaging studies show that high-frequency words elicit reduced neural activation in the left inferior frontal gyrus and temporal cortex (Graves et al., 2007; Nakic et al., 2006). This reduction of neural activation suggests greater efficiency in lexical access associated with high-frequency words. The locus of frequency effects has been attributed to both semantic and phonological stages of lexical access. According to interactive models of word production (e.g., Dell et al., 1997; Kittredge et al., 2008), frequency modulates the activation strength of word representations, influencing both lexical selection and the efficiency of phonological encoding. Other accounts have suggested a phonological-level locus of frequency, where speech error data show that low-frequency words are more susceptible to phonologically related errors than high-frequency words, in both neurotypical speakers and individuals with aphasia (Dell, 1990; Schwartz et al., 2004).

Familiarity

Familiarity refers to the subjective sense of how well a word is known or experienced by a speaker (Gernsbacher, 1984). While familiarity is often correlated with frequency, it differs in that

it reflects personal and contextual exposure to words. High-familiarity words tend to elicit faster and more accurate responses in naming and lexical decision tasks (Balota et al., 2004; Lambon Ralph et al., 1998). These words are thought to have richer semantic representations, which facilitate their activation during lexical retrieval (Ellis & Morrison, 1998). In individuals with aphasia or semantic degradation (e.g., svPPA), unfamiliar words are more likely to be omitted, misnamed, or circumlocuted (Hirsh & Ellis, 1994; Lambon Ralph et al., 1998; Wilson et al., 2010). This evidence suggests that familiarity affects efficient semantic access in lexical retrieval.

Age of Acquisition

AoA refers to the typical age at which a word is learned. Words acquired early in life tend to be more robustly represented in the mental lexicon and are retrieved more efficiently than later-acquired words (Morrison & Ellis, 1995; Juhasz, 2005). Although this property is also correlated with frequency, research has shown that AoA effects persist even when frequency is controlled, which suggests an independent contribution of AoA to lexical access (Brysbaert & Ghyselinck, 2006). Two prominent theoretical accounts have been proposed to explain the locus of AoA effects: the phonological completeness hypothesis and the arbitrary mapping hypothesis. The phonological completeness hypothesis (Brown & Watson, 1987; Gerhand & Barry, 1998) posits that AoA effects arise at the level of phonological representation. According to this view, the phonology of early-acquired words is stored more holistically and completely, whereas later-acquired words are represented in a more segmented way due to increasing lexical demands. While segmentation offers storage efficiency, it introduces phonological processing costs, which makes late-acquired words more difficult to assemble for production. This hypothesis aligns with findings that late-acquired words show increased vulnerability to phonological retrieval failures and errors (e.g., Kittredge et al., 2008). In contrast, the arbitrary mapping hypothesis suggests that AoA

effects reflect differences in the consistency and efficiency of mappings between semantics and phonology. According to this account, early-acquired words benefit from being learned when the language system is highly plastic, allowing strong, well-integrated connections to form between meaning and sound (Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006). These words become deeply embedded in the lexical-semantic system and shape its overall structure, making them easier to retrieve despite the inherently arbitrary nature of word-to-meaning associations. For example, although there is no systematic relationship between the concept *dog* and the phonological form */dɔg/*, this word is typically acquired early and is retrieved with high accuracy due to its well-established semantic-phonological mappings. In contrast, a word like *vase* is acquired much later in life and exhibits lower naming accuracy, likely because it had to be integrated into a more established and less plastic system with less efficient mappings between semantics and phonology (Brysbaert & Ellis, 2016; Bonin et al., 2004). Neuroimaging research has provided insights into the neural correlates of AoA, with greater activation of the left superior temporal gyrus and left inferior frontal gyrus for late-acquired words, regions implicated in phonological processing and lexical retrieval (Colombo & Burani, 2002; Cortese & Khanna, 2007). In clinical populations such as individuals with post-stroke aphasia and Alzheimer's disease, AoA has been found to be a significant predictor of naming performance, such that late-acquired words were more prone to error (Holmes et al., 2006; Nickels & Howard, 1995).

Imageability

Imageability refers to the ease with which a word evokes a mental image. Words with high imageability (e.g., “apple”) are typically more concrete and are retrieved more readily than abstract words (e.g., “justice”) (West and Holcomb, 2000). High imageability facilitates semantic activation due to the richer conceptual representations associated with visual imagery (Connell &

Lynott, 2012). In neurotypical adults, imageability consistently predicts performance in naming, lexical decision, and memory tasks (Khanna & Cortese, 2021; Strain & Herdman, 1999). Clinically, imageability is a robust predictor of naming success in semantic impairments, particularly in svPPA, where low-imageability words are disproportionately impaired (Jefferies et al., 2008). The dual coding theory posits that imageable words benefit from both verbal and non-verbal (imaginal) encoding pathways, which enhances their resilience in the face of semantic degradation (Paivio, 1991). This theory has been supported by neuroimaging evidence that showed that processing high-imageability words activates both left-hemisphere language areas and right-hemisphere regions associated with imagery, providing a neural basis for the dual coding advantage (Sabsevitz et al., 2005).

Word Length

Word length, usually measured in number of phonemes or syllables, influences retrieval primarily at the phonological encoding stage. Nickels & Howard (2004) have shown that number of phonemes is the best measure of word length effects, particularly in clinical populations. Shorter words are generally retrieved and articulated more quickly than longer ones (Jescheniak & Levelt, 1994). This effect is particularly pronounced in individuals with phonological deficits, such as those with conduction aphasia or lvPPA, who demonstrate deficits with holding and assembling phonological information (Nickels & Howard, 1995; Henry et al., 2016). Word length increases the processing load required for phonological assembly and articulation, and longer words are more susceptible to distortion or omission in individuals with limited phonological capacity (Howard & Gatehouse, 2006).

Phonological Neighborhood Density

Phonological neighborhood density (PND) refers to the number of words that differ from a given word by a single phoneme (Luce & Pisoni, 1998). Words from dense phonological neighborhoods face increased lexical competition during retrieval, which may delay or affect production (Vitevitch & Luce, 1999). However, the effect of PND is task-dependent: in naming tasks, sparse neighborhoods facilitate retrieval, while in recognition tasks, dense neighborhoods may be more facilitative (Vitevitch, 2002; Sadat et al., 2014). PND is implicated in the phonological stages of word production, where it influences the precision and efficiency of form-based retrieval. In individuals with phonological impairment, high PND taxes phonological encoding and increases the likelihood of interference, which can worsen word retrieval difficulties by activating multiple competitors (Gordon, 2002; Stemberger, 2004).

Semantic Neighborhood Density

SND refers to the number of semantically related concepts associated with a word. Words with many semantic neighbors benefit from associative priming but also face increased interference during selection. High SND can either facilitate performance through spreading activation or hinder it via competition, depending on task demands and participant profile, similar to PND (Hameau et al., 2019). For example, in semantic priming or lexical decision tasks, high SND typically facilitates processing by boosting activation of the target word through overlap in semantic features (Mirman & Magnuson, 2009). In contrast, in word retrieval tasks, high SND can lead to slower or less accurate responses due to increased competition among co-activated semantic neighbors (Schnur et al., 2006). This is particularly relevant in individuals with semantic impairments, where high SND may lead to increased semantic errors, as related concepts are co-activated but poorly differentiated (Hameau et al., 2019). These findings suggest that strong

semantic processing skills are necessary to constrain activation within dense semantic neighborhoods (Mirman, 2011). However, semantic competition can cascade into later stages of production, including phonological encoding, particularly in tasks like naming where full word retrieval is required. This interplay is especially evident when semantic control is compromised, leading to errors at multiple processing levels (Jefferies & Lambon Ralph, 2006). On the other hand, words with high SND may be retrieved more easily as prototypical items are embedded in dense semantic spaces due to their overlapping perceptual and functional features (McRae et al., 2005; Reilly & Desai, 2017).

Arousal

Arousal refers to the intensity of the emotional response a word elicits. In neurotypical individuals, high-arousal words (e.g., *rollercoaster*, *poison*) may be retrieved more rapidly due to their heightened salience and stronger encoding in episodic and affective memory systems (Citron, 2012; Larsen et al., 2008). Emotionally arousing words can be more resistant to degradation (Altarriba & Bauer, 2004; Kuperman et al., 2014). This resilience is thought to stem from encoding in both semantic and emotional memory systems, which reinforces their representations (Kuperman et al., 2014). There is also emerging evidence that under certain conditions, low-arousal words, especially when semantically rich or under less emotionally charged valence, may show better accuracy or are easier to process (e.g., Buchanan et al., 2006; Wu et al., 2023). This dual pattern shows that arousal may either facilitate or hinder retrieval depending on task demands and underlying vulnerabilities.

Valence

Valence captures the positive or negative emotional tone of a word. Words with positive valence (e.g., *hug*, *cake*) are typically retrieved more easily (Yang et al., 2013). In individuals with aphasia, valence modulates word retrieval in both recognition and production tasks. In a word recognition task, Newton et al. (2020) found that participants with post-stroke aphasia made fewer errors for positively valenced stimuli compared to neutral or negative words. In a picture naming task, Harmon et al. (2023) reported that negatively valenced stimuli led to decreased naming accuracy in both individuals with post-stroke aphasia and older neurotypical adult groups. These results suggest that strong negative emotions may interfere with lexical-semantic access by diverting attentional resources to emotion regulation processes (Harmon et al., 2023). Further, Macoir et al. (2019) showed that individuals with svPPA demonstrated significant impairments in recognizing emotional valence and basic emotions. When semantic memory performance was statistically controlled, these differences disappeared. This suggests that semantic memory plays a role in supporting the recognition of valence by providing conceptual structure and meaning to emotional stimuli. Therefore, the effects of valence on word retrieval may involve interactions between semantic and affective processing systems, although their exact locus within language production models remains unclear.

The Current Dissertation

Psycholinguistic properties are known to modulate the ease or difficulty of word retrieval in neurotypical individuals (e.g., Ellis & Lambon Ralph, 2000) and in individuals with acquired or progressive language disorders (e.g., Lambon Ralph et al., 1998; Nickels et al., 1995). However, little is known about how these properties influence word retrieval in lvPPA, a syndrome marked by word retrieval deficits and impaired verbal working memory (Gorno-Tempini et al., 2011). This

dissertation addresses this gap by examining the effects of psycholinguistic properties on word retrieval in individuals with lvPPA.

To capture the contextual variability of word retrieval, the dissertation examines performance across three word retrieval tasks that differ in their cognitive and linguistic demands: confrontation naming, verbal fluency, and discourse. Each task engages different components of the language system. Confrontation naming requires precise lexical access in response to visual stimuli and places strong demands on semantic and phonological systems (Dell et al., 1997; Levelt et al., 1999). Verbal fluency introduces executive demands such as inhibition, set-shifting, and working memory (Troyer et al., 1997), while discourse production includes integrated processes including lexical access, grammatical encoding, narrative structure, pragmatics, and episodic memory (Hannay et al., 2009; Seixmas-Lima et al., 2020). By analyzing how psycholinguistic properties predict retrieval across these tasks, this work aims to identify which effects are consistent across contexts and which are shaped by task-specific constraints. Such comparisons can reveal how psycholinguistic properties interact with underlying phonological and semantic impairments in lvPPA and can clarify how these interactions shape naming success, as well as informativeness in broader communicative contexts.

CHAPTER 2: PSYCHOLINGUISTIC PREDICTORS OF CONFRONTATION NAMING IN LOGOPENIC VARIANT PRIMARY PROGRESSIVE APHASIA[2]

Introduction

Word retrieval impairment is a core characteristic of logopenic variant primary progressive aphasia (lvPPA) and has been related to phonological processing deficits (Gorno-Tempini et al., 2011). Importantly, individuals with lvPPA exhibit word retrieval difficulty that are not uniform across all words. Rather, certain words tend to be consistently named more accurately than others. This variability suggests that specific word characteristics may influence naming performance in lvPPA, which underscores the importance of examining the psycholinguistic properties of words as potential determinants of naming success.

A large body of research has demonstrated that various psycholinguistic properties influence the efficiency of word retrieval (Brown & Watson, 1987; Brysbaert et al., 2018; Pisoni et al., 1985). These properties, which include frequency, age of acquisition (AoA), familiarity, word length, phonological neighborhood density (PND), semantic neighborhood density (SND), arousal, and valence, have been shown to affect different stages of lexical processing, which directly relate to word retrieval (Adelman et al., 2006; Juhasz, 2005; Vitevitch et al., 2008). Among these, frequency has consistently been found to influence word retrieval, indicating that higher-frequency words are accessed more efficiently than lower-frequency words (Kittredge et al., 2008). Similarly, AoA has been shown to exert a robust effect on word retrieval, with earlier-acquired words demonstrating faster and more accurate retrieval compared to later-acquired words (Juhasz, 2005). Familiarity has also been found to enhance naming accuracy, while the effects of word length and PND remain less consistent across studies (Lewellen et al., 1993; Pitt & Samuel, 2006;

[2] A version of this chapter has been published. Jebahi, F., Nickels, K. V., & Kielar, A. (2024a). Predicting confrontation naming in the logopenic variant of primary progressive aphasia. *Aphasiology*, *38*(4), 635-666. https://doi.org/10.1080/02687038.2023.2221998

Vitevitch & Luce, 2016). Additionally, recent research has explored the role of emotional properties, such as arousal and valence, in word retrieval, with some evidence suggesting that words associated with positive emotions are retrieved more efficiently (Kuperman et al., 2014; Recio et al., 2014).

The influence of these psycholinguistic properties on naming differs across clinical groups, such as post-stroke aphasia and semantic variant of PPA (svPPA) (Alyahya et al., 2020; Braun & Kiran, 2022; Lambon Ralph et al., 1998; Nickels & Howard, 1995). For example, while frequency and familiarity strongly predict naming accuracy in svPPA (Lambon Ralph et al., 1998), their effects are less less influential in post-stroke aphasia (Nickels & Howard, 1995). These differences reflect variations in the extent and nature of phonological and semantic impairments across these conditions (Lambon Ralph et al., 2002). Even within a single clinical population, findings have been mixed regarding which psycholinguistic properties most strongly influence naming (Bastiaanse et al., 2016; Lambon Ralph et al., 1998; Nickels & Howard, 1995). For example, in post-stroke aphasia, Nickels & Howard (1995) found that AoA and word length were strong predictors of naming accuracy while Nickels (1995) reported that imageability, familiarity, and word length influenced naming performance. Despite these investigations in other clinical populations, the extent to which psycholinguistic properties influence lexical retrieval in lvPPA remains unexplored.

An important consideration when evaluating lexical retrieval performance is the specific task used for assessment. Confrontation naming is a widely used measure of lexical retrieval and requires participants to name visually presented objects or pictures. This task isolates word retrieval from contextual cues and provides insight into lexical access independent of external facilitation (Mayer & Murray, 2003). Given that confrontation naming places high demands on

phonological and lexical-semantic processing, it can serve as a critical tool for examining the role of psycholinguistic properties in word retrieval difficulties observed in lvPPA. By analyzing performance on this task, psycholinguistic properties that contribute to naming success or failure can be identified.

This study aimed to examine the role of psycholinguistic properties in predicting confrontation naming performance in individuals with lvPPA. We analyzed the psycholinguistic properties of 60 words from the Boston Naming Test (BNT; Kaplan et al., 1983) to investigate their impact on naming accuracy in individuals with lvPPA. The primary objective was to assess the relative contributions of eight psycholinguistic properties to naming accuracy in lvPPA.

Methods

Participants

Recruitment Procedures

Fourteen individuals who met the diagnostic criteria for lvPPA were recruited for this study as part of the ongoing research studies in the Language and Neuroimaging Research Laboratory at the University of Arizona. Participation was open to both males and females, from all racial, ethnic, and socioeconomic background. Some of the participants were recruited through the Aphasia Groups at the University of Arizona's Speech, Language, and Hearing Sciences Clinic, and Friends of Aphasia in Tucson, Arizona. Others were referred by a neurologist at Banner–University Medical Center or identified by local speech-language pathologists in the Tucson area. Additionally, some participants reached out to the research team directly via ClinicalTrials.gov. All participants completed the full battery of behavioral assessments at a single time point, during their initial intake into the research study. Therefore, the data represent a cross-sectional snapshot of their language performance. All participants provided informed consent using documents

approved by the University of Arizona's Human Subjects Protection Program (**Appendix A**). The consent process included detailed information about the assessments. Participants and their families were provided with unlimited time to review the consent form at their convenience, and they were verbally reminded that they could withdraw from the study at any time without penalty or explanation.

A control group of 16 neurologically unimpaired adults was recruited from the broader Tucson community through community outreach efforts, and the Alzheimer's Prevention Registry. All recruitment efforts were done using advertisements approved by the University of Arizona's Human Subjects Protection Program. Recruitment was open to individuals of any sex, educational background, or racial/ethnic background. All control participants provided informed consent using documents also approved by the University of Arizona's Human Subjects Protection Program (**Appendix B)**. The consent process outlined the details of behavioral assessments. They were given as much time as they needed to review the consent materials before agreeing to participate.

All participants completed a self-report questionnaire to collect basic demographic details, including age, sex, educational background, handedness, languages spoken, and overall health history (**Appendix C)**. Additionally, individuals with lvPPA provided information related to the onset and diagnosis of their condition.

Inclusion and Exclusion Criteria

The inclusion criteria for individuals with lvPPA were: (1) a confirmed diagnosis of lvPPA without co-occurring neurological or psychiatric conditions, (2) a minimum score of 5 on the BNT, (3) native proficiency in English, and (4) normal or corrected-to-normal hearing and vision. Individuals were excluded if they had a history of neurological disorders other than lvPPA, such as stroke, epilepsy, multiple sclerosis, or Parkinson's disease. Exclusion criteria were a history of traumatic brain injury with loss of consciousness exceeding five minutes and prior treatment for

drug or alcohol abuse. All individuals in this group had been diagnosed with PPA by a neurologist before enrolling in the study, though the specific variant was not always determined at the time of diagnosis. PPA diagnosis was established based on progressive deterioration of language function, with initial and early-stage deficits primarily affecting language rather than other cognitive domains. The research team confirmed lvPPA classification through behavioral testing and clinical records, following the criteria outlined by Gorno-Tempini et al. (2011). Specifically, lvPPA was identified by speech production difficulties characterized by word retrieval deficits and/or phonemic paraphasias, as well as significant impairments in sentence repetition, while semantic, syntactic, and motor speech abilities remained relatively preserved.

For the neurologically healthy control participants, they were required to have no history of neurological or psychiatric conditions, be native English speakers, and have normal or corrected-to-normal hearing and vision. Similar to the lvPPA group, individuals were excluded if they had a history of traumatic brain injury with prolonged loss of consciousness, prior substance abuse treatment, or any diagnosed neurological disorders.

Demographic Characteristics

A summary of the demographic characteristics for both the lvPPA and neurotypical control groups is provided in **Table 2.1**. The lvPPA group consisted of 14 individuals (11 females, 3 males) ranging in age from 57 to 82 years (M = 69.71, SD = 6.57). The control group included 16 neurologically healthy adults (12 females, 4 males) with a mean age of 67.06 years (SD = 7.20). The two groups did not significantly differ in age at the time of testing, $t(28) = 1.05$, $p = .303$, nor in years of education, $t(17.22) = .84$, $p = .415$. Both groups were highly educated. Among individuals with lvPPA, years of formal education ranged from 12 to 27 years (M = 16.93, SD = 4.63), while the control group had an average of 15.81 years of education (SD = 2.01). The sex

distribution was comparable across groups, with females comprising 78.5% of the lvPPA group and 75% of the control group ($\chi^2(1) = .05$, $p = .825$).

Handedness was assessed using the Edinburgh Handedness Inventory (Williams, 2010), which required participants to indicate their preferred hand for various daily activities, such as writing, brushing their teeth, and striking a match. All control participants were right-handed. Within the lvPPA group, one participant was classified as ambidextrous but reported being functionally right-handed.

Within the lvPPA group, symptom onset was most commonly reported in the 60s (M = 67.36, SD = 6.21), which aligns with previous research that suggests PPA often develops around the sixth and seventh decade of life (Mesulam et al., 2014). The most frequently reported initial symptom was difficulty retrieving words, followed by impairments in spelling and effortful speech production.

Table 2.1. *Group demographic characteristics of participants with logopenic variant primary progressive aphasia (lvPPA) with comparison to neurotypical controls.*

	LvPPA group (n = 14)	Control group (n = 16)	t/χ^2, p
Age at testing (years)	69.71 (6.57)	67.06 (7.20)	1.05, .303
Education (years)	16.93 (4.63)	15.81 (2.01)	.84, .415
Handedness (R; L)	13; 0	16; 0	1.18, .277
Sex (F; M)	11; 3	12; 4	.05, .825

Values for age at testing and education are presented as M (SD). Values for handedness and sex are presented as counts. Independent samples t-tests were conducted for age at testing and education, and t-values reported in the last column. Chi-square tests were conducted for handedness and sex, and χ^2-values reported in the last column. R = Right-handed, L = Left-handed, F = Female, M = Male.

Behavioral Characteristics

All participants completed a comprehensive assessment battery that evaluated their cognitive and language abilities across multiple domains, with results summarized in **Table 2.2**. Prior to inclusion in the study, participants' hearing was screened using a pure-tone audiometry screening, and vision status was assessed through a self-report questionnaire to confirm normal or corrected-to-normal sensory functioning.. All assessments took place in a quiet environment to

minimize distractions. The full testing process required, on average, five to six sessions for individuals with lvPPA and two sessions for control participants, with each session lasting approximately two hours. Breaks were provided as needed, and participants were compensated at a rate of $10 per hour. All testing sessions were audio recorded, with data securely stored in an electronic database using numeric subject codes assigned at the time of enrollment. These codes were used on all assessment protocols, and hard copies were securely stored in a locked cabinet within the research laboratory.

Nonlinguistic Cognitive Function

To evaluate overall cognitive status, the Montreal Cognitive Assessment (MoCA; Nasreddine, 2005) was administered. This screening tool assesses multiple cognitive domains, including visuospatial function, naming, memory, attention, language, and orientation (**Table 2.2**). The control group received an average MoCA score of 26.19 (*SD* = 2.34, range = 26 – 30) out of 30, consistent with normal cognitive functioning. In contrast, individuals with lvPPA scored within the "moderate cognitive impairment" range, with a mean score of 12.86 (*SD* = 6.74, range = 4 – 25) out of 30.

Executive functioning was assessed using the number-letter switching task from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) and the digit span forward and digit span backward subtests from the Wechsler Memory Scale-Fourth Edition (WMS-4; Wechsler, 2008). The trail-making number-letter switching task required participants to alternate between numbers and letters in ascending order (e.g., 1 > A > 2 > B). Scaled scores, based on completion time, revealed that the lvPPA group were significantly impaired compared to controls, $t(25) = 7.82$, $p < .001$. The digit span forward and digit span backward examined phonological short-term and working memory. Performance on both tasks was significantly lower in the lvPPA

group compared to controls, for digit span forward, $t(27) = 4.87$, $p < .001$, and for digit span backward, $t(24.44) = 5.23$, $p < .001$, (see **Table 2.2**).

Visuospatial abilities were measured using the symbol cancellation and complex figure from the Kaplan-Baycrest Neurocognitive Assessment (KBNA; Leach, 2000). In the symbol cancellation task, participants were given two minutes to identify and mark a target symbol among distractors. Individuals with lvPPA were significantly impaired, $t(12.60) = 2.49$, $p = .028$. In the complex figure copy task, they were first asked to copy a figure with no time constraints. Immediately afterward, they were instructed to redraw the figure from memory. Performance on the copying task was unimpaired, while the performance on the immediate recall was lower compared to controls, $t(25) = 4.63$, $p < .001$ (see **Table 2.2**).

Episodic memory was evaluated using the Warrington Memory Test (WMT) for face recognition (Warrington, 1984). Participants were briefly shown a series of 50 faces and asked to categorize each as "pleasant" or "unpleasant" to facilitate encoding. Following this, they were presented with pairs of faces and asked to identify the one previously seen. The lvPPA group performed comparably to controls in this task (**Table 2.2**).

Aphasia Severity

To assess overall language abilities in individuals with lvPPA, the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007) was administered. Participants exhibited language impairment, with a mean Aphasia Quotient (AQ) of 80.90 (SD = 10.11). Consistent with phonological processing and working memory deficits that are characteristic of lvPPA (Gorno-Tempini et al., 2011), naming was the most impaired domain, with an average score of 68.09%, followed by repetition at 76.91% (see **Table 2.2**).

Sensorimotor Skills

Performance on sensorimotor tasks that assessed auditory and visual processing is summarized in **Table 2.2**. Auditory processing was evaluated using two subtests from the Arizona Phonological Battery (APB; Beeson et al., 2010): Rhyme Judgment and Minimal Pair Judgment. These tasks were adapted from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay et al., 1996). The lvPPA group exhibited significant deficits compared to controls in the rhyme judgment task, $t(12.60) = 2.61$, $p = .022$, but not the minimal pair judgment task. This aligns with phonological working memory deficits observed in lvPPA (Gorno-Tempini et al., 2011; Henry et al., 2016). Impaired rhyme judgment reflects these deficits, as it relies more heavily on phonological working memory, whereas preserved minimal pair judgment suggests early-stage phonemic perception and discrimination remain intact (Macoir et al., 2021).

Visual-orthographic processing was assessed using three PALPA subtests: letter identification in reverse orientation subtest (PALPA 18), lower-to-upper case matching subtest (PALPA 19), and upper-to-lower case matching subtest (PALPA 20). Performance on these visual tasks was comparable between individuals with lvPPA and controls (**Table 2.2**).

Speech production abilities were assessed through repetition. The word repetition task was administered using the repetition of single words PALPA subtest (PALPA 11). Individuals with lvPPA showed significant impairment in this task, $t(13.16) = 3.13$, $p = .008$. Nonword repetition, which was assessed using the Children's Nonword Repetition Test (CNRT; Gathercole et al., 1994), was also impaired relative to controls, $t(13.35) = 4.21$, $p < .001$.

Motor control of speech production was examined using the Apraxia of Speech Rating Scale (ASRS; Duffy, 2006), with apraxia of speech severity rated on a 0 to 4 scale, as follows: as follows: 0 = not present; 1 = detectable but infrequent; 2 = frequent but not pervasive; 3 = nearly always evident but not marked in severity; 4 = nearly always evident and marked in severity. As

detailed in **Table 2.2**, the lvPPA group did not show impaired motor control for speech. Nonetheless, it is of note that two participants exhibited varying degrees of apraxia of speech: one had mild-to-moderate apraxia, and a one displayed mild apraxia, which did not impact speech intelligibility.

Naming, Reading, and Spelling Abilities

On the 60-item BNT (Kaplan et al., 1983) that assessed confrontation naming, individuals with lvPPA demonstrated significantly lower accuracy, $t(13.45) = 6.67$, $p < .001$, with a mean average score of 48.69% ($SD = 25.64$) compared to controls, who had a mean score of 94.79% ($SD = 3.59$). Generative naming tasks from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) showed further impairment. Specifically, participants with lvPPA showed significant deficits in both category, $t(23.61) = 13.27$, $p < .001$, and letter fluency, $t(27) = 10.78$, $p < .001$, tasks compared to control participants (see **Table 2.2**).

To assess single-word reading and spelling, participants completed the Arizona Battery for Reading and Spelling (ABRS; Beeson et al., 2010). As shown in **Table 2.2**, the control group performed near ceiling levels across all conditions. In contrast to controls, individuals with lvPPA exhibited significant impairments in reading of both real words and nonwords ($M = 91.79$, $SD = 9.92$, $t(13.17) = 2.97$, $p = .011$, and $M = 77.31$, $SD = 17.39$, $t(13.10) = 4.33$, $p < .001$, respectively) and showed impaired spelling for both real words and nonwords ($M = 72.75$, $SD = 19.91$, $t(9.39) = 3.96$, $p = .003$ and $M = 59.34$, $SD = 25.52$, $t(11.94) = 4.52$, $p < .001$, respectively). Nonword reading and spelling were more impaired than real word reading and spelling in lvPPA (reading: $t(12) = -3.52$, $p = .002$; spelling $t(9) = -1.64$, $p = .067$), which is consistent with the well-documented phonological impairment in lvPPA (Gorno-Tempini et al., 2011). This relative impairment suggests a breakdown in grapheme-to-phoneme (reading; decoding) and phoneme-to-grapheme (spelling; encoding) conversions which are hallmark features of phonological alexia and

dysgraphia observed in lvPPA (Rapcsak et al., 2009). These impairments reflect a reliance on lexical-semantic pathways which arises as a compensation for degraded phonological processing abilities (Brambati et al., 2009).

Central Cognitive Processes for Language

Sublexical phonological processing skills were evaluated using tasks from the Arizona Phonological Battery (APB) that required participants to identify and manipulate sounds in words and nonwords. These tasks included sound deletion, sound blending, and sound replacement. The lvPPA group demonstrated significant impairments across all phonological tasks relative to controls, with accuracy rates varying based on task complexity (see **Table 2.2**). Although the control group also found sound replacement more challenging than other tasks, their accuracy remained significantly higher compared to lvPPA, $t(13.32) = 6.50$, $p < .001$.

Semantic processing abilities were evaluated through four tasks that measured receptive vocabulary and conceptual knowledge. These tasks included the Peabody Picture Vocabulary Test – Fourth Edition (PPVT – 4; Dunn & Dunn, 2007) to assess single-word comprehension, the Camel and Cactus Test (CCT; Adlam et al., 2010) for object relationship knowledge, and two PALPA subtests that assessed written word-to-picture matching (PALPA 48) and auditory synonym judgment (PALPA 49). Across all semantic tasks, the lvPPA group were significantly impaired compared to controls. The CCT was the most challenging task, such that participants with lvPPA achieved a mean accuracy of 68.03%, compared to 91.31% in controls, $t(12.46) = 4.29$, $p < .001$. Greater difficulty with the CCT may stem from its high reliance on associative semantic processing (Rogalsky et al., 2018). The test requires conceptual integration across multiple semantic features and levels of complexity, which is not always direct. This conceptual integration relies on temporoparietal regions often affected in lvPPA (Hoffman et al., 2014; Leyton et al., 2015). Performance on other semantic measures remained above 85% accuracy for the lvPPA group.

Syntactic processing was assessed using three subtests from the Northwestern Assessment of Verbs and Sentences (NAVS; Thompson, 2012). The Sentence Comprehension Test required participants to select the correct picture from two options in response to a spoken sentence. The Sentence Production Priming Test required participants to generate a grammatically equivalent sentence based on the provided model. The Argument Structure Production Test (ASPT) assessed the ability to construct grammatical sentences by producing correct subject, object, and verb use, as well as the absence of paraphasic errors when individual words were provided in written format. The lvPPA group showed impairments across all syntactic tasks relative to controls (see **Table 2.2**). Sentence comprehension was mildly impaired, with an average accuracy of 84.17%, $t(11.07) = 2.96$, $p = .013$. The SPPT, which posed greater demands on working memory, was the most challenging (51.82% accuracy), $t(10.02) = 3.90$, $p = .003$. However, performance on the ASPT, with an average score of 77.70%, $t(10.56) = 2.88$, $p = .015$, suggests that orthographic input may have facilitated sentence construction.

Table 2.2. *Language and cognitive assessment scores for participants with logopenic variant primary progressive aphasia (lvPPA) compared to neurotypical controls (NC).*

Task, Test (score type)	*n* lvPPA, NC	LvPPA *M* (*SD*)	NC *M* (*SD*)	*t*, *p*
Nonlinguistic Cognitive Function				
<u>General Cognition</u>				
Overall Cognitive Status, MoCA (/30)	14, 16	12.86 (6.74)	26.19 (2.34)	7.04, **< .001**
<u>Executive Function</u>				
Trail-Making Number-Letter Switching, D-KEFS (Scaled)	13, 14	3.54 (2.99)	11.50 (2.28)	7.82, **<.001**
Digit Span Forward, WMS–4 (Scaled)	13, 16	5.92 (2.87)	11.06 (2.79)	4.87, **< .001**
Digit Span Backward, WMS–4 (Scaled)	13, 16	5.92 (1.94)	11.19 (3.41)	5.23, **< .001**
<u>Visuospatial Processing</u>				
Symbol Cancellation, KBNA (%)	13, 16	82.18 (21.06)	96.88 (3.70)	2.49, **.028**

Complex Figure – Copy, KBNA (%)	11, 16	74.55 (26.41)	86.56 (8.11)	1.46, .171
Complex Figure – Immediate Recall, KBNA (Scaled)	11, 16	5.36 (3.67)	11.38 (3.05)	4.63, **< .001**
<u>Episodic Memory</u>				
Memory for Faces, WMT (%)	14, 16	73.43 (10.00)	77.50 (6.30)	1.35, .187
Aphasia Severity				
Spontaneous Speech Content, WAB – R (%)	13, NT	86.92 (12.51)	NT	NA
Fluency, WAB – R (%)	13, NT	80.77 (12.56)	NT	NA
Comprehension, WAB – R (%)	11, NT	88.59 (10.06)	NT	NA
Repetition, WAB – R (%)	11, NT	76.91 (12.24)	NT	NA
Naming, WAB – R (%)	11, NT	68.09 (16.62)	NT	NA
Aphasia Quotient, WAB – R (%)	11, NT	80.90 (10.11)	NT	NA
Sensorimotor Skills				
<u>Auditory Processing</u>				
Rhyme Judgment, APB (%)	13, 16	83.65 (19.30)	97.81 (3.40)	2.61, **.022**
Minimal Pair Judgment, APB (%)	13, 16	85.00 (26.87)	98.75 (2.58)	1.84, .091
<u>Visual-Orthographic Processing</u>				
Letter Identification, PALPA 18 (%)	13, 16	97.22 (4.94)	98.26 (2.24)	.70, .492
Lower-Upper Case Matching, PALPA 19 (%)	11, 16	96.50 (8.51)	99.76 (.96)	1.26, .234
Upper-Lower Case Matching, PALPA 20 (%)	11, 16	96.85 (7.46)	100.00 (.00)	1.40, .192
<u>Speech Production</u>				
Word Repetition, PALPA 11 (%)	13, 16	90.94 (8.70)	98.68 (2.12)	3.13, **.008**
Nonword Repetition, CNRT (%)	13, 16	70.00 (19.01)	92.81 (4.99)	4.21, **< .001**
Motor Control, ASRS (Scaled)	14, 16	.29 (.83)	.00 (.00)	-1.30, .218
Naming, Reading, and Spelling Abilities				
<u>Naming</u>				
Confrontation Naming, BNT (%)	14, 16	48.69 (25.64)	94.79 (3.59)	6.67, **< .001**
Category Fluency, D-KEFS (Scaled)	13, 16	2.31 (1.70)	14.69 (3.22)	13.27, **< .001**
Letter Fluency, D-KEFS (Scaled)	13, 16	5.15 (2.76)	14.56 (1.93)	10.78, **< .001**
<u>Reading and Spelling</u>				
Word Reading, ABRS (%)	14, 16	91.79 (9.92)	99.69 .85)	2.97, **.011**
Nonword Reading, ABRS (%)	13, 15	77.31 (17.39)	98.67 (3.99)	4.33, **< .001**
Word Spelling, ABRS (%)	10, 16	72.75 (19.91)	97.97 (3.68)	3.96, **.003**

Nonword Spelling, ABRS (%)	12, 15	59.34 (25.52)	93.33 (5.88)	4.52, **< .001**
Central Cognitive Processes for Language				
Phonological Skills				
Sound Deletion, APB (%)	13, 16	64.62 (30.72)	99.69 (1.25)	4.11, **< .001**
Sound Blending, APB (%)	12, 16	47.92 (30.63)	87.19 (11.69)	4.22, **< .001**
Sound Replacement, APB (%)	12, 16	33.89 (27.63)	88.33 (10.33)	6.50, **< .001**
Semantic Skills				
Single-Word Comprehension, PPVT – 4 (Scaled)	12, 16	96.08 (7.65)	115.81 (10.89)	5.35, **< .001**
Object Association, CCT (%)	13, 16	68.03 (19.40)	91.31 (2.96)	4.29, **< .001**
Written Word-to-Picture Matching, PALPA 48 (%)	11, 16	93.41 (7.85)	99.38 (1.12)	2.50, **.031**
Synonym Judgment, PALPA 49 (%)	14, 16	85.12 (12.12)	92.29 (2.71)	3.68, **.002**
Syntactic Processing				
Sentence Comprehension, NAVS (%)	12, 16	84.17 (18.04)	99.58 (1.14)	2.96, **.013**
Sentence Production Priming, NAVS (%)	11, 16	51.82 (40.56)	99.58 (1.67)	3.90, **.003**
Argument Structure Production, NAVS (%)	11, 11	77.70 (22.73)	97.73 (3.79)	2.88, **.015**

Values in bold = significant impairment relative to neurotypical controls ($p < .05$); NT = Not tested, NA = Not applicable

Materials and Measures

Confrontation Naming

Lexical retrieval ability was evaluated using a confrontation naming task, the BNT, which consists of 60 black-and-white line drawings of objects (Kaplan et al., 1983). The BNT is a well-established tool for assessing confrontation naming in adults. In accordance with standardized administration procedures, each participant was presented with one picture at a time and instructed to verbally identify the depicted object. Participants were given a maximum of 20 seconds to produce a spontaneous response. Accuracy was scored based on the established criteria provided by Nicholas et al. (1989).

Psycholinguistic Properties

Psycholinguistic properties of the BNT items were obtained primarily using the South Carolina Psycholinguistic Metabase (SCOPE; Gao et al., 2022), which aggregates multiple

psycholinguistic databases. Familiarity ratings were drawn from a published study specifically examining the familiarity of BNT items (Himmanen et al., 2003). In the current study, we extracted eight key psycholinguistic characteristics: (1) Frequency, calculated as the base-10 logarithm of frequency norms derived from the SUBTLEXUS corpus (Brysbaert & New, 2009); (2) Familiarity, defined as the subjective rating of how commonly a word is encountered, scored on a 5-point scale (Himmanen et al., 2003); (3) AoA, which reflects the estimated age in years at which a word is typically learned, based on subjective ratings (Kuperman et al., 2012); (4) Word length, operationalized as the number of phonemes per word and retrieved from the English Lexicon Project (ELP; Balota et al., 2007); (5) PND, determined as the number of words that can be obtained by changing one phoneme while preserving the identity and position of the other phonemes, as reported in the ELP (Balota et al., 2007); (6) SND, which quantifies the mean semantic distance between a given word and its neighbors (Shaoul & Westbury, 2010); (7) Arousal, which measures the intensity of emotional activation associated with a word on a scale from 0 (calming) to 1 (highly arousing) (Mohammad, 2018); and (8) Valence, an indicator of the emotional positivity or negativity of a word, with values ranging from 0 (negative) to 1 (positive) (Mohammad, 2018). The psycholinguistic property values for each BNT item are provided in **Appendix D**.

Procedure

Participants completed the BNT in a quiet, well-lit room. Standardized administration procedures were followed, in which participants were presented with each item in the BNT in its original order. If a participant failed to provide a correct response of its name within 20 seconds and did not recognize the picture, the examiner provided a semantic cue (e.g., “It is a type of tool” for *saw*). If the participant still failed to name the item or indicated recognition of the picture but

could not retrieve its name, a phonemic cue was provided (e.g., "/s/"). Responses were recorded verbatim and later scored as correct, incorrect, or correct with cueing based on standardized scoring guidelines. Only spontaneously correct (i.e., those produced without cueing) and incorrect responses were considered in subsequent analyses. Following data collection, naming accuracy for each participant was coded as a binary outcome (correct/incorrect) for each item. Psycholinguistic property values for each of the BNT items were extracted from relevant databases, as detailed in the Psycholinguistic Properties subsection above. These values were then matched to each participant's naming data to allow for statistical analyses.

Data Analyses

Data checks were conducted before running statistical analyses to confirm adherence to normality assumptions. The skewness and kurtosis values were within the expected range (skewness: −1 to +1; kurtosis: −2 to +2), which supports the assumption of normality. In addition, correlation matrices were computed for all psycholinguistic properties to characterize interrelationships among these variables. Pearson's correlation coefficients were calculated for all pairs of psycholinguistic variables. These matrices provide descriptive information about shared variance among lexical properties.

The primary objective of this study was to investigate the relationship between psycholinguistic properties and naming accuracy in individuals with lvPPA. To explore this, Pearson's correlation analyses were conducted to examine associations between naming accuracy and the extracted psycholinguistic features of BNT words. Additionally, multiple linear regression analyses were employed to determine the extent to which these psycholinguistic properties collectively contributed to naming performance. In this analysis, BNT naming accuracy served as

the dependent variable, and the extracted psycholinguistic measures were entered as predictor variables.

Results

Table 2.3 presents the correlation matrix for the psycholinguistic properties included in the study. Several significant relationships were observed, including significant positive correlations between frequency and familiarity, and strong negative correlations between frequency and AoA. Additionally, frequency showed a strong positive association with SND. Word length was negatively correlated with both frequency and PND.

Table 2.3. *Pearson's correlation matrix for psycholinguistic properties of BNT stimuli*

	Frequency	Familiarity	AoA	Word Length	PND	SND	Arousal	Valence
Frequency	1							
Familiarity	.45***	1						
AoA	-.67***	-.43***	1					
Word Length	-.38**	-.15	.27*	1				
PND	.52***	.22	-.32*	-.72***	1			
SND	.75***	.25	-.41**	-.26*	.27*	1		
Arousal	-.20	-.23	.29*	.32*	-.25	-.06	1	
Valence	.16	.30*	-.28*	.13	-.05	.22	-.18	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 2.4 presents the results of bivariate correlations between each psycholinguistic property and naming accuracy in individuals with lvPPA. Significant correlations emerged between naming accuracy and frequency, familiarity, AoA, word length, and SND, whereas PND, arousal, and valence did not show significant relationships with accuracy.

Table 2.4. *Pearson's correlations between psycholinguistic properties and naming accuracy for the lvPPA group (n = 14)*

	Frequency	Familiarity	AoA	Word length	PND	SND	Arousal	Valence
r	.69***	.50***	-.78***	-.27*	.13	.41**	-.23	.24

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

To examine the extent to which psycholinguistic properties contributed to naming accuracy in lvPPA, multiple linear regression analyses were conducted. The results, summarized in **Table 2.5**, indicated that the regression model was statistically significant, $R^2 = .69$, $F(8,46) = 12.57$, $p < .001$. Among the psycholinguistic properties examined, AoA was the only significant predictor of naming accuracy when controlling for other variables ($\beta = -.55$, $p < .001$), such that words acquired earlier in life were named more accurately than later-acquired words.

Table 2.5. *Results of regression analyses showing the effects of psycholinguistic properties on BNT naming accuracy in lvPPA group*

Psycholinguistic property	*B*	SE	β	*t, p*
Frequency	.12	.06	.32	1.94, .06
Familiarity	.14	.09	.15	1.48, .145
AoA	**-.08**	**.02**	**-.55**	**-4.29, < .001**
Word length	.02	.02	.11	.70, .487
PND	.03	.04	.10	.63, .534
SND	-.20	.28	-.09	-.71, .482
Arousal	.01	.15	.01	.03, .976
Valence	.01	.18	.01	.03, .977

Values in bold = significant predictor of BNT naming accuracy ($p < .05$); *B* and β represent the unstandardized and standardized regression weights of multiple linear regression, respectively.; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density; SE = Standard error.

Discussion

This study investigated the relationship between psycholinguistic properties and naming accuracy in individuals with lvPPA. Naming deficits are a hallmark of lvPPA (Gorno-Tempini et al., 2011; Henry & Gorno-Tempini, 2010; Mesulam et al., 2014), yet these difficulties do not affect all words equally. Some lexical items appear to be more vulnerable to deterioration than others, which suggests that certain psycholinguistic properties may influence naming accuracy. A rich body of research in neurotypical populations and individuals with post-stroke aphasia and svPPA has established the impact of components such as frequency, AoA, and familiarity on lexical access and naming performance (Alario et al., 2004; Alyahya et al., 2020; Barry et al., 1997;

Hinojosa et al., 2010; Lambon Ralph et al., 1998; Nickels & Howard, 1995; Wilson et al., 2009). However, the extent to which these psycholinguistic properties influence naming accuracy on confrontation naming in lvPPA remains unexplored. The present study examined the influence of these variables on naming performance in lvPPA using a commonly used confrontation naming task, the BNT.

Influence of Psycholinguistic Properties on Naming Accuracy

Regression analyses revealed that AoA was the strongest psycholinguistic predictor of naming accuracy, such that words acquired earlier in life were more resistant to deterioration in lvPPA. This facilitative effect of AoA on naming has been well-documented across various clinical populations, including individuals with post-stroke aphasia and unclassified PPA (Brysbaert & Ellis, 2016; Lambon Ralph et al., 1998; Nickels & Howard, 1995; Ukita et al., 1999). The robustness of this effect aligns with the view that AoA reflects a fundamental property of lexical learning, where words learned earlier in life develop stronger representations in the mental lexicon (Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006). This notion is also supported by the arbitrary mapping hypothesis, which suggests that early-acquired words have richer and more established representations in both semantic and phonological systems, which in turn make them more resistant to impairments (Ellis & Lambon Ralph, 2000). The durability of these representations has been attributed to increased neuroplasticity during early childhood, which is thought to facilitate lexical consolidation and long-term retention in the face of lexical retrieval deficits (Brysbaert & Ellis, 2016; Chang et al., 2019; Lambon Ralph & Ehsan, 2006).

While AoA effects are widely recognized and have been shown to be robust in neurotypical and clinical populations, there has been ongoing debate regarding their precise locus in lexical processing. Many studies have suggested that AoA primarily influences post-semantic lexical

retrieval, at the phonological level (Alario et al., 2004; Barry et al., 1997; Brown & Watson, 1987; Gerhand & Barry, 1999; Perret & Bonin, 2019). For instance, Barry et al. (1997) proposed that AoA affects the activation of phonological representations necessary for word retrieval, occurring after semantic access but before articulation. They argued that earlier acquired words are learned as whole phonological units, which facilitates more efficient retrieval in adulthood (phonological completeness hypothesis; Brown & Watson, 1987; Gerhand & Barry, 1998; Morrison & Ellis, 1995). However, another account emphasizes the role of the consistency and efficiency of mappings between semantics and phonology such that early-acquired words benefit from being learned when the language system is highly plastic, allowing strong, well-integrated connections to form between meaning and sound (Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006). Given that lvPPA is characterized by phonological impairment rather than primary semantic degradation, the AoA effect observed here may, at least in part, reflect vulnerabilities at the phonological level. However, it is difficult to identify whether the AoA effects in lvPPA arises from phonological mechanisms solely or from an interplay of phonological and semantic mechanisms. Therefore, further research is needed to disentangle the relative contributions of phonological and semantic factors in mediating AoA effects in lvPPA.

Future Directions

The current study provided insights into the relationship between psycholinguistic properties as well as components and naming accuracy in lvPPA. However, the use of a defined set of words from the BNT limits the variability of the stimuli investigated and may not reflect the dynamic, generative nature of word retrieval. A less-restrictive task that involves word production, such as a word fluency task, could better capture lexical retrieval at the word level in lvPPA. Additionally, because all participants were presented with the same set of words, we were unable

to investigate the relationship between psycholinguistic properties and underlying cognitive mechanisms in individuals with lvPPA (their semantic and phonological abilities). Future research should explore how individual differences in semantic and phonological processing interact with psycholinguistic properties to influence naming accuracy. The second study in this dissertation, discussed in the following chapter, investigated psycholinguistic differences in a generative naming task, the animal fluency, and addressed these limitations.

CHAPTER 3: PSYCHOLINGUISTIC AND COGNITIVE DETERMINANTS OF GENERATIVE NAMING IN LOGOPENIC VARIANT PRIMARY PROGRESSIVE APHASIA[3]

Introduction

Naming impairment is a hallmark deficit in the logopenic variant primary progressive aphasia (lvPPA) and is commonly assessed using confrontation naming tasks in research and clinical settings (Henry & Grasso, 2018). In the study presented in Chapter 2, we examined the relationship between psycholinguistic properties and naming accuracy in lvPPA using this task. While this study provided valuable insights, the use of a fixed set of words from the Boston Naming Test (BNT; Kaplan et al., 1983) constrained the variability of lexical items. Additionally, because all participants named the same words, the study could not account for individual differences in phonological and semantic abilities and explore how these factors interact with psycholinguistic properties to influence word retrieval. Building on the findings of the study presented in Chapter 2 and addressing some of its shortcomings, the present study explored lexical retrieval in lvPPA using a generative naming paradigm. This approach allows for an examination of both the quantity of words generated (i.e., total correct responses) and the qualitative characteristics of those words (i.e., their psycholinguistic properties) where word produced differ across participants.

Unlike confrontation naming tasks, which require individuals to retrieve specific words in response to visual stimuli, generative naming tasks, such as verbal fluency, assess lexical retrieval in a more dynamic and cognitively demanding manner. These tasks require individuals to generate as many words as possible within a semantic category (semantic fluency) or beginning with a given letter (phonemic fluency) under time constraints. This approach measures overall word retrieval

[3] A version of this chapter has been published. Jebahi, F., Nickels, K. V., & Kielar, A. (2024b). Patterns of performance on the animal fluency task in logopenic variant of primary progressive aphasia: A reflection of phonological and semantic skills. *Journal of Communication Disorders*, *108*, 106405.

ability and can also capture the efficiency of lexical search, the organization of semantic knowledge, and the ability to sustain word production over time (Shao et al., 2014; Troyer et al., 1997). Verbal fluency tasks are widely used in neuropsychological assessments because they are quick to administer, sensitive to cognitive impairment, and provide a lesser constrained context than tasks with a predetermined set of words (Biesbroek et al., 2016; Rofes et al., 2020).

It has been argued that semantic fluency tasks, such as the animal fluency task, largely depend on the integrity of the semantic system (Biesbroek et al., 2016; Shao et al., 2014; Vonk et al., 2019). However, phonological abilities may also contribute to performance on these tasks, as word retrieval requires intact phonological representations to execute speech output effectively (Rofes et al., 2020). Given the phonological deficits characteristic of lvPPA, studying verbal fluency performance in this population may provide important insights into the relative contributions of phonological and semantic impairments to lexical retrieval. Additionally, analyzing the psycholinguistic properties of retrieved words allows for a detailed examination of whether individuals with lvPPA favor words with certain properties (e.g., higher frequency, shorter length, earlier acquired in life), and for the exploration of how phonological and semantic abilities drive these patterns of retrieval.

As discussed in earlier chapters, psycholinguistic properties of words, such frequency, familiarity, age of acquisition (AoA), word length, phonological neighborhood density (PND), semantic neighborhood density (SND), arousal, and valence have been shown to influence naming performance in both neurotypical and clinical populations (Alario et al., 2004; Kittredge et al., 2008; Perret et al., 2014; Rofes et al., 2023). These properties interact with phonological and semantic processing, which are critical for successful word retrieval. For example, it has been argued that AoA and word frequency are associated with both phonological and semantic abilities

(Ellis & Lambon Ralph, 2000; Graves et al., 2007). Similarly, familiarity and SND have been linked to the semantic system, and PND and word length have been related to phonological processing (Bormann, 2011; Graves et al., 2007; Nickels & Howard, 1995).

These relationships between psycholinguistic properties and cognitive domains have been explored by associating patterns of semantic and phonological impairment with word production performance in relation to participants characteristics. For example, familiarity has been linked to semantic abilities based on the observed familiarity effect in individuals with the semantic variant of PPA, who demonstrate prominent semantic deficits (Lambon Ralph et al., 1998). However, no study has systematically examined these effects in a generative naming task, where word selection is not externally constrained. This limitation restricts our ability to investigate how individuals navigate lexical search when retrieval is self-initiated.

The present study aimed to characterize verbal fluency performance in lvPPA by examining both quantitative (total number of correct words generated) and qualitative (psycholinguistic properties of generated words) aspects of word retrieval. Particularly, our aims were to (1) investigate whether individuals with lvPPA produce fewer correct responses compared to neurotypical controls, (2) examine the psycholinguistic properties of the words produced and their relationship to the total number of correct responses, and (3) assess the contributions of phonological and semantic abilities to verbal fluency performance, in terms of the number and psycholinguistic characteristics of correct words generated.

Methods

Participants

Recruitment Procedures

A total of 15 individuals diagnosed with lvPPA were recruited as part of multiple research studies in the Language and Neuroimaging Research Laboratory at the University of Arizona. Enrollment included individuals from all racial, ethnic, and socioeconomic backgrounds, and both male and female participants were eligible. The recruitment process involved several channels: the Aphasia Group at the University of Arizona's Speech, Language, and Hearing Sciences Clinic, a neurologist at Banner–University Medical Center, local speech-language pathologists in Tucson, and ClinicalTrials.gov. Of the 15 individuals with lvPPA included in the current study, 12 also participated in Study 1 (Chapter 2; Jebahi et al., 2024a). All participants contributed data that were collected during initial intake. All participants provided written informed consent using forms approved by the University of Arizona's Human Subjects Protection Program (**Appendix A**). The consent process ensured that participants received comprehensive information about the study, including details of behavioral assessments. Participants with lvPPA and their family members had multiple days to review the consent documents, and they were reminded that participation was voluntary and could be discontinued at any time.

The control group consisted of 20 neurologically healthy adults, recruited through advertisements approved by advertisements approved by the Human Subjects Protection Program at the University of Arizona. These advertisements were used in the Tucson community and for recruitment through the Alzheimer's Prevention Registry. The study included no restrictions on sex, race, ethnicity, or educational background. As with the lvPPA group, all control participants provided written consent using materials approved by the University of Arizona's Human Subjects Protection Program (**Appendix B)**. The consent process included a thorough explanation of

behavioral assessments, and participants were given time to review the documents before making a decision about their involvement.

Both groups completed a self-reported demographic questionnaire covering key personal details such as age, sex, education level, handedness, languages spoken, and general health history (**Appendix C**). In addition, individuals with lvPPA provided further details regarding their diagnosis and disease progression (e.g., time at diagnosis).

Inclusion and Exclusion Criteria

Participants with lvPPA were included in the study if they met the following requirements: (1) a neurologist-confirmed diagnosis of PPA without any additional neurological or psychiatric disorders, (2) a clinical diagnosis of lvPPA, based on international consensus criteria (Gorno-Tempini et al., 2011), (3) a minimum of one correct response on the animal fluency task, (4) native-level English proficiency, and (5) normal or corrected-to-normal hearing and vision. Individuals were excluded if they had a history of other neurological conditions, such as stroke, epilepsy, multiple sclerosis, or Parkinson's disease. Additional exclusion criteria included a history of significant head trauma involving a loss of consciousness exceeding five minutes, as well as previous treatment for substance abuse.

All participants in the lvPPA group had received a prior diagnosis of PPA from a neurologist before enrolling in the study, and this diagnosis was based on a pattern of progressive language impairment, with deficits predominantly affecting linguistic abilities at disease onset and in the early stages. The research team further confirmed lvPPA classification through a combination of behavioral assessments and available clinical data. The primary characteristics of lvPPA included slowed and effortful speech production due to word retrieval challenges and/or phonemic paraphasias, as well as significant difficulty with sentence repetition, while semantic, syntactic, and motor speech functions remained relatively intact.

The control group consisted of neurologically healthy adults who met the following inclusion criteria: (1) no history of neurological or psychiatric conditions, (2) native proficiency in English, and (3) normal or corrected-to-normal vision and hearing. As with the lvPPA group, exclusion criteria included prior traumatic brain injury with prolonged loss of consciousness, a history of substance use disorders requiring treatment, and any diagnosed neurological condition.

Both groups completed a self-report questionnaire to document demographic details and health history. Additionally, all participants underwent screening to verify that they met study eligibility requirements.

Demographic Characteristics

Table 3.1 presents a summary of the demographic characteristics of the lvPPA and neurotypical control groups. The lvPPA group consisted of 15 individuals (10 females, 5 males), while the control group included 20 neurologically healthy adults (15 females, 5 males). The two groups were matched in both age, $t(33) = .60$, $p = .554$, and years of education, $t(33) = .25$, $p = .806$. The average age of participants with lvPPA was 69.33 years ($SD = 6.29$), whereas the control group had a mean age of 67.95 years ($SD = 7.10$). Both groups had high levels of formal education. Individuals in the lvPPA group had between 12 and 27 years of education, with an average of 16.93 years ($SD = 4.20$), while the control group reported an average of 16.65 years of education ($SD = 2.54$). The groups had comparable sex distributions, with females making up 75% of the lvPPA group and 66.67% of the control group ($\chi^2(1) = .04$, $p = .833$).

Handedness was assessed using the Edinburgh Handedness Inventory (Williams, 2010), which evaluates dominant hand use across various daily tasks such as writing and brushing teeth. All participants in the control group were right-handed. Within the lvPPA group, one participant was categorized as ambidextrous but functionally identified as right-handed.

Participants in the lvPPA group most commonly reported symptom onset in their 60s (M = 67.00, SD = 6.39), consistent with previous research that suggests PPA typically manifests around the age of 65 (Mesulam et al., 2014). The most frequently reported early symptom was difficulty with word retrieval, followed by spelling challenges and effortful speech production.

Table 3.1. *Group demographic characteristics of participants with logopenic variant primary progressive aphasia (lvPPA) with comparison to neurotypical controls (NC)*

	LvPPA	NC	t/χ^2, p
Age at testing (years)	69.33 (6.29)	67.95 (7.10)	.60, .554
Education (years)	16.93 (4.20)	16.65 (2.54)	.25, .806
Handedness (R; A)	14; 1	20; 0	1.37, .241
Sex (F; M)	11; 4	14; 6	.04, .833

Values for age at testing and education are presented as M (SD). Values for handedness and sex are presented as counts. Independent samples t-tests were conducted for age at testing and education, and t-values reported in the last column. Chi-square tests were conducted for handedness and sex, and χ^2-values reported in the last column. R = Right-handed, A = Ambidextrous, F = Female, M = Male.

Behavioral Characteristics

Participants underwent a comprehensive assessment battery designed to evaluate their cognitive and linguistic abilities across multiple domains, as depicted in **Table 3.2**. Prior to testing, hearing was confirmed using a pure-tone hearing screening, and vision was verified via participant self-report using a standardized questionnaire to ensure normal or corrected-to-normal sensory functioning.. All assessments took place in a quiet setting to minimize distractions. The full evaluation took approximately five to six sessions for individuals with lvPPA, while control participants completed testing in two sessions. Each session lasted around two hours, with breaks provided as needed. Participants received compensation of $10 per testing hour. All testing sessions were recorded in audio format and subsequently stored in an electronic database. Each participant was assigned a numeric subject code at enrollment, which was used to label all data files and paper records securely kept in a locked cabinet within the research lab.

Nonlinguistic Cognitive Function

To assess overall cognitive status, the Montreal Cognitive Assessment (MoCA; Nasreddine, 2005) was administered, measuring visuospatial function, naming, memory, attention, language, and orientation (**Table 3.2**). The control group had an average score of 26.50 (*SD* = 2.29, range = 26 – 30) out of 30, reflecting no cognitive impairment, while the lvPPA group scored an average of 14.20 (*SD* = 7.62, range = 6 – 28), indicative of moderate cognitive impairment.

Executive function was examined using the number-letter trail-making switching task from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001), which requires alternating connections between numbers and letters in ascending order (e.g., 1 → A → 2 → B…). Response times were converted to scaled scores, which showed significant impairment in the lvPPA group relative to controls, $t(30) = 8.92$, $p < .001$. Phonological short-term and working memory were assessed through the digit span forward and backward subtests of the Wechsler Memory Scale–Fourth Edition (WMS-4; Wechsler, 2008), where the lvPPA group also demonstrated significantly lower performance than controls for digit span forward, $t(33) = 5.59$, $p < .001$, and for digit span backward, $t(28.23) = 5.42$, $p < .001$, (**Table 3.2**).

Performance on visuospatial tasks was evaluated using the symbol cancellation and complex figure copy tasks from the Kaplan-Baycrest Neurocognitive Assessment (KBNA; Leach, 2000). In the symbol cancellation task, participants had two minutes to mark target symbols among distractors, while in the figure copy task, they first copied a complex figure and later attempted to reproduce it from memory. The lvPPA group performed significantly lower than controls on the symbol cancellation task, $t(13.36) = 2.90$, $p = .012$, and the immediate recall of the complex figure, $t(30) = 5.44$, $p < .001$ (**Table 3.2**).

The Warrington Memory Test (Warrington, 1984) was administered to assess memory for faces. Participants viewed 50 faces, rating each as "pleasant" or "unpleasant" to encourage

encoding. Afterward, they completed a two-choice memory task where they had to choose the face that had been encoded. Participants with lvPPA performed comparably to controls in this task (**Table 3.2**).

Aphasia Severity

To evaluate language abilities in individuals with lvPPA, the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007) was used. Results indicated language impairment, with a mean Aphasia Quotient (AQ) of 79.65 (*SD* = 10.40). In line with phonological processing deficits, which are a hallmark of lvPPA (Gorno-Tempini et al., 2011), naming ability was the most affected, with an average of 64.50% (*SD* = 21.22), followed by repetition, which had a mean score of 76.25% (*SD* = 12.18).

Sensorimotor Skills

Sensorimotor skills related to auditory and visual-orthographic processing were assessed using tasks adapted from the Arizona Phonological Battery (APB; Beeson et al., 2010) and the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay et al., 1996). Auditory processing was evaluated through the Rhyme Judgment and Minimal Pair Judgment subtests of the APB. Individuals with lvPPA exhibited deficits compared to controls in the rhyme judgment task, $t(14.36) = 2.29$, $p = .038$. Visual-orthographic processing, measured using PALPA subtests for letter identification (PALPA 18) and case matching (PALPA 19 and PALPA 20), showed no significant differences between groups (see **Table 3.2**).

Speech production abilities were examined through repetition tasks. Individuals with lvPPA demonstrated impairments in both word, $t(32) = 2.55$, $p = .016$, and nonword, $t(17.07) = 3.22$, $p = .005$, repetition, although their average accuracy on the word repetition task, evaluated using PALPA 11 ($M = 93.65$, $SD = 5.29$) was higher than that of the nonword repetition task, evaluated using the Children's Nonword Repetition Test (CNRT; Gathercole et al., 1994), with an

average score of 73.83 (*SD* = 19.91). Additionally, motor control of speech production was assessed using the Apraxia of Speech Rating Scale (ASRS; Duffy, 2006), with apraxia of speech rated on a severity scale from 0 to 4 as follows: 0 = not present; 1 = detectable but infrequent; 2 = frequent but not pervasive; 3 = nearly always evident but not marked in severity; 4 = nearly always evident and marked in severity. On a group level, the difference between the lvPPA and control groups was not significant. Nonetheless, one individual with lvPPA displayed mild-to-moderate apraxia (score of 3) and another participant exhibited a mild form (score of 1) that did not significantly affect intelligibility.

Naming, Reading, and Spelling Abilities

Performance on the 60-item Boston Naming Test (BNT; Kaplan et al., 1983) revealed significant deficits in individuals with lvPPA, who demonstrated lower accuracy (M = 50.33, SD = 29.45) in comparison to control participants (M = 95.00, SD = 3.46), $t(14.29) = 5.84$, $p < .001$. Additional difficulties were observed in verbal fluency tasks from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001). Specifically, individuals with lvPPA exhibited impairments in both category, $t(33) = 12.27$, $p < .001$, and letter, $t(33) = 11.81$, $p < .001$, fluency (see **Table 3.2**).

The Arizona Battery for Reading and Spelling (ABRS; Beeson et al., 2010) was used to evaluate single-word reading and spelling abilities. Control participants performed near ceiling on these tasks, whereas compared to controls, the lvPPA group exhibited significant deficits in reading of real words and nonwords (M = 91.50, $t(14.15) = 2.87$, $p = .012$, and M = 76.42, $t(13.51) = 3.56$, $p = .003$, respectively) and in spelling accuracy of real words and nonwords (M = 63.75, $t(9.09) = 3.83$, $p = .004$ and M = 57.09, $t(12.74) = 4.52$, $p < .001$, respectively). Compared to real words, individuals with lvPPA showed greater difficulties with nonword reading and spelling (reading: $t(13) = -3.23$, $p = .003$; spelling: $t(9) = -1.22$, $p = .126$). This discrepancy reflects

impairments in phonological abilities, specifically decoding and encoding processes (the conversion between graphemes and phonemes) characteristic of phonological alexia and dysgraphia in lvPPA (Rapcsak et al., 2009). As phonological skills decline, individuals with lvPPA increasingly depend on lexical-semantic routes to support reading and spelling tasks (Brambati et al., 2009).

Central Cognitive Processes for Language

Central cognitive processes that support language were also examined, including phonological, semantic, and syntactic processing. Sublexical phonological skills were assessed using APB tasks that required participants to manipulate speech sounds through deletion, blending, as well as replacement. The lvPPA group demonstrated significant deficits across these tasks, with performance varying depending on task complexity (**Table 3.2**).

Semantic processing was examined using five tasks that test vocabulary knowledge and concept associations. These tasks included the Peabody Picture Vocabulary Test – Fourth Edition (PPVT – 4; Dunn & Dunn, 2007), which measures single-word comprehension, the Camel and Cactus Test (CCT; Adlam et al., 2010), which assesses conceptual knowledge of object relationships, and two PALPA subtests that evaluate written word-to-picture matching (PALPA 48) and auditory synonym judgment (PALPA 49). Individuals with lvPPA exhibited significant impairments across all semantic measures, with the CCT being particularly challenging (average accuracy of 68.54% in lvPPA compared to 91.48% in controls, $t(14.60) = 4.91$, $p < .001$). Nevertheless, participants with lvPPA maintained accuracy rates above 85% on other semantic tasks.

Syntactic abilities were evaluated using three subtests from the Northwestern Assessment of Verbs and Sentences (NAVS; Thompson et al., 2012). The Sentence Comprehension Test (SCT) required selecting a corresponding image in response to a spoken sentence. The Sentence

Production Priming Test (SPPT) involved producing a sentence that mirrored a given structure. The Argument Structure Production Test (ASPT) assessed sentence construction, including the correct use of subject, object, and verb. The lvPPA group displayed deficits in all syntactic tasks, with sentence comprehension showing mild impairment at an average accuracy of 85.78%. However, the SPPT showed greater challenges, with accuracy of 55.71%. Performance on ASPT (81.36%) suggested that orthographic input may have helped with sentence formation.

Table 3.2. *Group behavioral characteristics of participants with logopenic variant primary progressive aphasia (lvPPA) with comparison to neurotypical controls (NC)*

Task, Test (score type)	*n* lvPPA, NC	LvPPA *M* (*SD*)	NC *M* (*SD*)	*t*, *p*
Nonlinguistic Cognitive Function				
General Cognition				
Overall Cognitive Status, MoCA (/30)	15, 20	14.20 (7.62)	26.50 (2.29)	**6.07, < .001**
Executive Function				
Trail-Making Number-Letter Switching, D-KEFS (Scaled)	14, 18	3.00 (2.77)	11.33 (2.50)	**8.92, < .001**
Digit Span Forward, WMS–4 (Scaled)	15, 20	5.73 (2.76)	11.10 (2.85)	**5.59, < .001**
Digit Span Backward, WMS–4 (Scaled)	15, 20	5.87 (1.73)	11.00 (3.74)	**5.42, < .001**
Visuospatial Processing				
Symbol Cancellation, KBNA (%)	14, 20	78.10 (24.62)	97.33 (3.44)	**2.90, .012**
Complex Figure – Copy, KBNA (%)	12, 20	73.75 (24.78)	85.00 (7.43)	1.53, .151
Complex Figure – Immediate Recall, KBNA (Scaled)	12, 20	5.42 (3.63)	11.55 (2.72)	**5.44, < .001**
Episodic Memory				
Memory for Faces, WMT (%)	15, 20	72.53 (9.43)	76.90 (6.34)	1.64, .111
Aphasia Severity				
Spontaneous Speech Content, WAB – R (%)	15, NT	86.67 (11.75)	NT	NA
Fluency, WAB – R (%)	15, NT	79.33 (12.80)	NT	NA
Comprehension, WAB – R (%)	12, NT	88.33 (9.64)	NT	NA
Repetition, WAB – R (%)	12, NT	76.25 (12.18)	NT	NA

Naming, WAB – R (%)	12, NT	64.50 (21.22)	NT	NA
Aphasia Quotient, WAB – R (%)	12, NT	79.65 (10.40)	NT	NA
Sensorimotor Skills				
Auditory Processing				
Rhyme Judgment, APB (%)	15, 20	87.17 (19.04)	98.50 (2.50)	**2.29, .038**
Minimal Pair Judgment, APB (%)	15, 20	86.67 (25.26)	98.88 (2.50)	1.87, .083
Visual-Orthographic Processing				
Letter Identification, PALPA 18 (%)	14, 20	97.02 (4.81)	98.47 (2.11)	1.06, .305
Lower-Upper Case Matching, PALPA 19 (%)	12, 20	96.79 (8.17)	99.81 (.86)	1.27, .229
Upper-Lower Case Matching, PALPA 20 (%)	12, 20	97.12 (7.17)	100.00 (.00)	1.39, .096
Speech Production				
Word Repetition, PALPA 11 (%)	14, 20	93.65 (5.29)	97.78 (4.16)	**2.55, .016**
Nonword Repetition, CNRT (%)	15, 20	73.83 (19.91)	91.25 (7.59)	**3.22, .005**
Motor Control, ASRS (Scaled)	15, 20	.27 (.80)	.00 (.00)	-1.29, .217
Naming, Reading, and Spelling Abilities				
Naming				
Confrontation Naming, BNT (%)	15, 20	50.33 (29.45)	95.00 (3.46)	**5.84, < .001**
Category Fluency, D-KEFS (Scaled)	15, 20	2.53 (2.03)	14.35 (3.28)	**12.27, < .001**
Letter Fluency, D-KEFS (Scaled)	15, 20	5.20 (2.70)	14.60 (2.01)	**11.81, < .001**
Reading and Spelling				
Word Reading, ABRS (%)	15, 20	91.50 (10.93)	99.63 (.92)	**2.87, .012**
Nonword Reading, ABRS (%)	14, 19	76.42 (22.91)	98.42 (3.75)	**3.56, .003**
Word Spelling, ABRS (%)	10, 20	63.75 (28.49)	98.38 (2.84)	**3.83, .004**
Nonword Spelling, ABRS (%)	13, 19	57.09 (28.95)	93.95 (6.14)	**4.52, < .001**
Central Cognitive Processes for Language				
Phonological Skills				
Sound Deletion, APB (%)	15, 20	64.33 (34.22)	99.75 (1.19)	**4.01, < .001**
Sound Blending, APB (%)	14, 20	48.93 (31.27)	87.75 (12.62)	**4.40, < .001**
Sound Replacement, APB (%)	13, 20	37.44 (30.31)	85.50 (13.12)	**5.40, < .001**
Semantic Skills				
Single-Word Comprehension, PPVT – 4 (Scaled)	12, 20	96.08 (7.65)	117.40 (11.27)	**5.78, < .001**
Object Association, CCT (%)	15, 20	68.54 (17.90)	91.48 (3.02)	**4.91, < .001**

Written Word-to-Picture Matching, PALPA 48 (%)	12, 20	92.50 (8.59)	99.63 (.92)	**2.86, .015**
Synonym Judgment, PALPA 49 (%)	15, 20	86.44 (11.78)	97.17 (2.71)	**3.46, .003**
Syntactic Processing				
Sentence Comprehension, NAVS (%)	15, 20	85.78 (17.11)	99.67 (1.03)	**3.14, .007**
Sentence Production Priming, NAVS (%)	14, 20	55.71 (40.69)	99.50 (1.63)	**4.02, < .001**
Argument Structure Production, NAVS (%)	14, 14	81.36 (21.30)	98.21 (3.46)	**2.92, .011**

Values in bold = significant impairment relative to neurotypical controls ($p < .05$); NT = Not tested, NA = Not applicable

Materials and Measures

Generative Naming

Participants completed an animal fluency task from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001), where they were given 60 seconds to generate as many animal names as possible. Responses were recorded and scored based on D-KEFS guidelines, with animal names and specific breeds considered correct (e.g., *Dalmatian*), while repetitions, adjectives, and superordinate terms (e.g., *animal*) were excluded. Two independent raters reviewed the audio and video recordings for scoring accuracy and achieved 98% inter-rater reliability. Discrepancies were resolved through discussion with the first author.

Psycholinguistic Properties

Psycholinguistic properties for each correctly produced word were obtained from the South Carolina Psycholinguistic Metabase (SCOPE; Gao et al., 2022). The extracted variables included: (1) Frequency, defined as the base-10 logarithm of frequency norms (Brysbaert & New, 2009); (2) Familiarity, defined as the subjective rating of how commonly a word is encountered, scored on a 7-point scale (Scott et al., 2019), (3) AoA, which corresponds to the estimated age in years at which a word is typically learned (Kuperman et al., 2012); (4) Word length, defined as the number of phonemes per word and extracted from the English Lexicon Project (ELP; Balota et al., 2007); (5) PND, operationalized as the number of words that can be generated by altering a single phoneme while maintaining the position and identity of all other phonemes, based on data from

the ELP (Balota et al., 2007); (6) SND, which quantifies the mean semantic distance between a given word and its semantic neighbors (Shaoul & Westbury, 2010); (7) Arousal, which measures the intensity of emotional activation associated with a word on a scale from 0 (calming) to 1 (highly arousing) (Mohammad, 2018); and (8) Valence, a measure of the emotional positivity or negativity of a word, with values ranging from 0 (negative) to 1 (positive) (Mohammad, 2018).

Procedure

Participants completed the animal fluency task in a quiet, well-lit room. They were instructed to name as many animals as possible within 60 seconds. Responses were scored for accuracy according to the guidelines outlined in the D-KEFS (Delis et al., 2001). Animal names and specific breeds (e.g., *Dalmatian*) were considered correct, while repetitions, adjectives, superordinate-level terms (e.g., *amphibians*), and pet names (e.g., *Buddy*) were considered incorrect. All correct responses were recorded in their singular form. All sessions were audio recorded. The recordings were later reviewed offline to confirm scoring accuracy by two independent scorers, with an interrater reliability of 98%. Discrepancies were resolved by the author of this dissertation.

Each participant's performance was quantified based on the total number of correct words generated. In addition to this quantitative measure, psycholinguistic properties were examined for the words produced. Each correct response was matched to its corresponding psycholinguistic values, including frequency, familiarity, AoA, word length, PND, SND, arousal, and valence, as extracted from established databases. For each participant, an average value for each psycholinguistic property was calculated across all correct responses, such that each individual had a unique set of psycholinguistic scores reflecting their word generation profile.

Data Analyses

Before conducting statistical analyses, data checks were performed to verify assumptions of normality and sphericity. Skewness and kurtosis values were examined and found to be within acceptable ranges (skewness: −1 to +1; kurtosis: −2 to +2), confirming that the data followed a normal distribution. Group differences in the total number of correctly generated words were assessed using independent samples *t*-tests. To compare the psycholinguistic properties of the words produced by each group, an analysis of covariance (ANCOVA) was conducted while controlling for the total number of correct responses.

In addition, a correlation matrix was computed for the psycholinguistic properties of words produced by individuals with lvPPA to characterize interrelationships among lexical variables. Pearson's correlation coefficients were calculated for all pairs of psycholinguistic properties based on the words produced by the lvPPA group. The correlation matrix is presented in **Table 3.4**.

To identify which psycholinguistic properties predicted the total number of correct words generated, a forward stepwise linear regression analysis was conducted. Additionally, to explore the relationship between psycholinguistic properties and broader language abilities in individuals with lvPPA, Principal Component Analysis (PCA) with varimax rotation was used to extract key language components. The resulting factor scores were then entered simultaneously in a single step into multiple linear regression models to examine their contributions to the total number of correct words produced and the psycholinguistic properties of those words. All statistical analyses were performed using SPSS 28.0 (IBM Corp., Armonk, NY, USA).

To further examine whether phonological and semantic abilities mediated the relationship between psycholinguistic properties and word retrieval, mediation analyses were conducted using SmartPLS-4 (Ringle et al., 2022). This software provides a graphical interface that facilitates

mediation modeling and bootstrapping analyses. The bootstrapping procedure, based on 5000 resamples, was employed to estimate the direct and indirect effects and ensured a robust evaluation of the relationships between variables. For all analyses, statistical significance was set at $p < .05$.

Results

Total Number of Correct Words and Their Psycholinguistic Properties

Table 3.3 summarizes the findings from independent samples *t*-tests and separate ANCOVAs that were conducted to compare the performance of individuals with lvPPA and neurotypical controls in terms of the total number of correct words generated and their associated psycholinguistic properties. The results demonstrated that participants with lvPPA produced significantly fewer correct words than controls during the animal fluency task, $t(33) = -10.16$, $p < .001$. Additionally, when controlling for the total number of correct responses, individuals with lvPPA tended to produce words with an earlier AoA compared to the control group, $F(1,32) = 4.38$, $p = .044$.

Table 3.3. *Differences in total number of correct words generated and their psycholinguistic between the lvPPA and neurotypical control (NC) groups on the animal fluency task*

	LvPPA	NC	$t/F, p^{\dagger}$
Total number of correct words	**6.67 (4.12)**	**23.80 (5.46)**	**-10.16, < .001**
Frequency	3.17 (.39)	2.56 (.11)	2.36, .135
Familiarity	6.05 (.32)	5.49 (.16)	3.71, .063
AoA	**4.25 (.63)**	**5.57 (.29)**	**4.38, .044**
Word length	4.13 (.73)	4.65 (.36)	.04, .841
PND	17.82 (6.19)	12.47 (2.42)	1.16, .289
SND	.60 (.04)	.54 (.02)	1.68 .204
Arousal	.44 (.05)	.46 (.03)	.32, .575
Valence	.58 (.07)	.52 (.02)	1.00, .324

Values for the lvPPA and NC groups are presented as *M* (*SD*). Independent samples *t*-tests were used to compare the total number of correct words between groups, with *t*-value reported in the last column (first row). ANCOVAs were conducted for psycholinguistic properties, †adjusting for total number of correct words, with *F*-values reported in the last column (all but first row). Significant differences are provided in bold.

Relationships Among Psycholinguistic Properties in Individuals with lvPPA

Table 3.4. shows the correlation matrix for psycholinguistic properties of words produced by individuals with lvPPA. The observed correlations revealed substantial shared variance among core lexical variables, consistent with established relationships in the psycholinguistic literature.

Table 3.4. *Pearson correlation matrix for psycholinguistic properties of words produced by individuals with lvPPA*

	Frequency	Familiarity	AoA	Word length	PND	SND	Arousal	Valence
Frequency	1							
Familiarity	.82***	1						
AoA	-.92***	-.87***	1					
Word length	-.75***	-.49***	.61***	1				
PND	.61***	.43*	-.52***	-.68***	1			
SND	.96***	.74***	-.86***	-.74***	.68***	1		
Arousal	-.07	-.21	.13	.18	-.38*	-.03	1	
Valence	.55***	.78***	-.65***	-.15	.14	.44**	-.26	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Relationship Between the Total Number of Correct Words and Their Psycholinguistic Properties

A forward stepwise linear regression analysis was conducted to determine the extent to which psycholinguistic properties contributed to the number of correct words generated in individuals with lvPPA (see **Table 3.5**). This analysis included only the lvPPA group, with the total number of correct words as the dependent variable and all eight psycholinguistic properties entered as predictors. The results indicated that AoA was the only significant predictor, with individuals who produced a greater number of correct words tending to generate words acquired later in life, whereas those who produced fewer correct words tended to generate words learned earlier in life.

Table 3.5. *Results of forward stepwise linear regression analysis showing the contribution of psycholinguistic variables to the number of correctly generated words on the animal fluency task in logepnic primary progressive aphasia (lvPPA)*

Predictor	*B*	SE	β	*t*, *p*
AoA	5.41	1.01	.83	5.34, < .001

Other psycholinguistic variables (frequency, familiarity, word length, PND, SND, arousal, and valence) were included in the analysis but did not reach statistical significance ($p > .05$). $F(1,14) = 28.53$, $p < .001$; $R^2 = .69$; AoA = Age of acquisition.

Contributions of Phonological and Semantic Abilities to the Number of Correct Words and Their Psycholinguistic Properties

Table 3.6 presents the results of the PCA with varimax rotation, which identified two distinct factors with eigenvalues greater than one that captured underlying phonological and semantic processing abilities and accounted for 83.31% of the variance. The first component (41.70% of variance) reflected semantic processing, with strong loadings from the single-word comprehension, written word-to-picture matching, synonym judgment, and object association tasks. The second component (41.61% of variance) was associated with phonological processing and was characterized by the shared variance among the sound blending, sound replacement, and sound deletion subtests from the APB. The Kaiser-Meyer-Olkin (KMO) measure confirmed the sample's adequacy for PCA (KMO = .67).

Table 3.6. *Component loading and results of principal component analysis with varimax rotation*

	Component 1: Semantic Processing	Component 2: Phonological Processing
Variance explained (%)	41.70	41.61
Single-word comprehension	**.94**	.17
Synonym judgment	**.90**	.21
Written word-to-picture matching	**.84**	.32
Object association	**.55**	.47
Sound blending	.17	**.94**
Sound replacement	.33	**.91**
Sound deletion	.26	**.90**

Values in bold = component loadings greater than .50. Extraction method: Principal component analysis after varimax rotation. Rotation converged in three iterations. Kaiser–Meyer–Olkin measure of sampling adequacy = .67. Bartlett's test of sphericity = 53.98, $df = 21$, $p < .001$.

To investigate how phonological and semantic abilities influenced animal fluency performance in lvPPA, factor scores from the PCA were entered simultaneously in a single step into multiple linear regression models to predict the total number of correct words and their psycholinguistic properties (**Table 3.7**). Both semantic and phonological processing abilities significantly predicted the total number of correct words (semantic processing: β = .49, p = .019; phonological processing: β = .74, p = .002), suggesting that stronger abilities in these domains were associated with a greater output in word generation. Additionally, both components significantly predicted word frequency, AoA, and SND, with stronger semantic and phonological processing abilities linked to words that were lower in frequency, acquired later in life, and had fewer semantic neighbors. Furthermore, semantic abilities predicted familiarity (β = -.82, p = .003) and arousal (β = -.62, p = .049), indicating that individuals with greater semantic abilities produced less familiar and less arousing words.

Table 3.7. *Results of multiple linear regression analyses predicting the contribution of semantic and phonological processing components to the number of correct words generated and their psycholinguistic properties on the animal fluency task in logepnic primary progressive aphasia (lvPPA)*

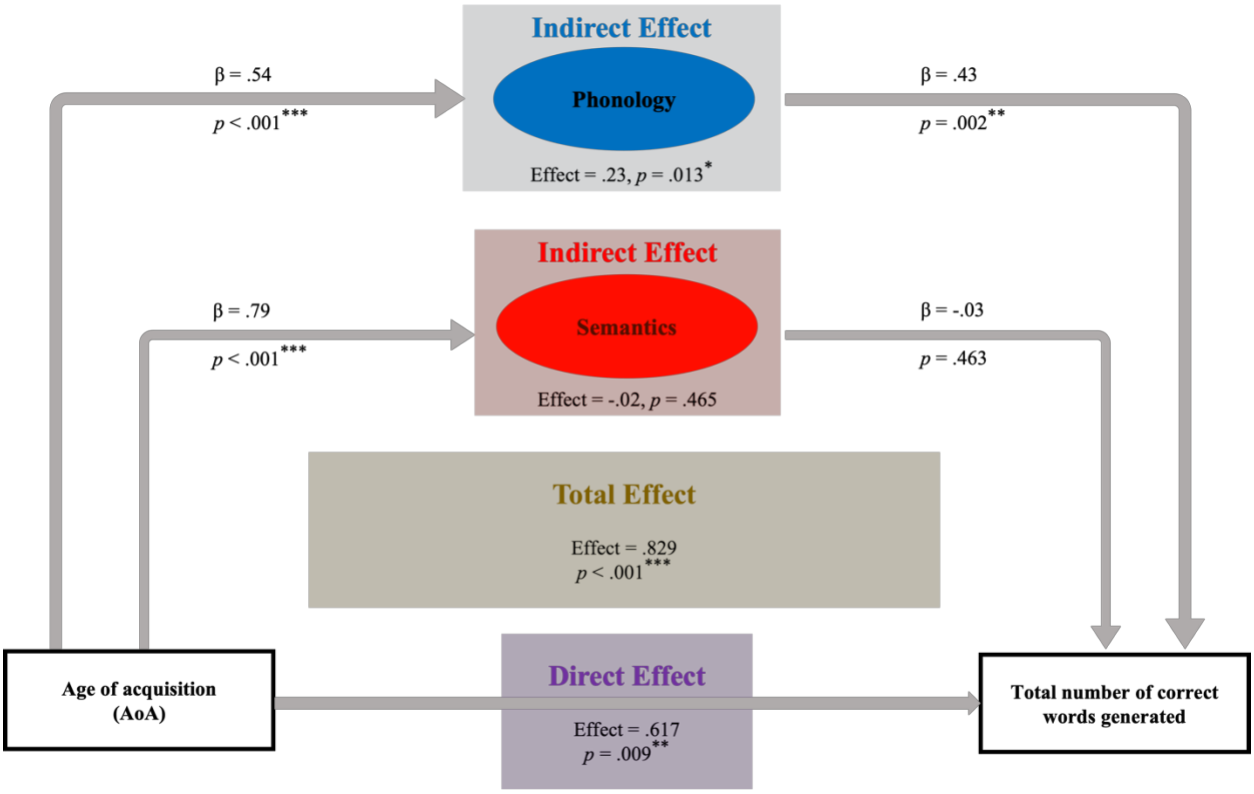
	R^2	F	Semantic Processing		Phonological Processing	
			β	t, p	β	t, p
Total number of correct words	.78	14.18	**.49**	**2.93, .019**	**.74**	**4.45, .002**
Frequency	.72	10.26	**-.66**	**-3.51, .008**	**-.54**	**-2.86, .021**
Familiarity	.70	9.23	**-.82**	**-4.22, .003**	-.16	-.81, .44
AoA	.70	9.34	**.71**	**3.66, .006**	**.44**	**2.29, .05**
Word length	.50	4.02	.46	1.83, .11	.54	2.17, .06
PND	.36	2.29	.29	1.04, .331	-.53	-1.87, .09
SND	.60	5.82	**-.52**	**-2.29, .05**	**-.57**	**-2.53, .035**
Arousal	.26	1.44	**-.62**	**-2.32, .05**	.23	.84, .426
Valence	.43	3.04	-.46	-1.50, .172	.24	.79, .453

Values in bold = significant contribution of semantic/phonological processing to total number of correct words/psycholinguistic properties (p < .05); AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density.

Mediating Effects of Phonological and Semantic Abilities on the Relationship Between Total Number of Correct Words and Age of Acquisition

Since AoA was the only significant predictor of total word generation in lvPPA, and both phonological and semantic abilities were found to influence total word count and AoA, a mediation analysis was conducted to explore whether phonology and semantics mediated the relationship between total correct words and AoA. This analysis examined both direct and indirect effects and assessed how AoA influenced total word generation when phonological and semantic components were considered as mediators. **Figure 3.1** presents the results of the mediation analysis.

Figure 1.1. *Mediation model with age of acquisition (AoA; predictor), phonology and semantics (mediators), and total number of correct words generated (outcome)*



Findings indicated that phonology partially mediated the relationship between AoA and total word generation (indirect effect = .23, p = .013), whereas semantics did not play a mediating role. This suggests that stronger phonological skills facilitate the production of words acquired

later in life. However, the direct effect of AoA on total word generation remained significant, accounting for 74.43% of the total effect (direct effect = .62, p = .009), even when phonological and semantic abilities were included in the model. Thus, while phonology played a partial mediating role, AoA remained a significant psycholinguistic determinant of word generation in individuals with lvPPA.

Discussion

This study investigated the influence of psycholinguistic properties on animal fluency performance in individuals with lvPPA. Verbal fluency deficits are common in lvPPA (Henry & Gorno-Tempini, 2010; Mesulam et al., 2014), yet the extent to which psycholinguistic properties influence word retrieval during fluency tasks in this population remains understudied. The present study examined quantitative and qualitative aspects of animal fluency performance in lvPPA, focusing on the total number of correct responses and the psycholinguistic properties of generated words. Additionally, we explored the contributions of phonological and semantic processing abilities to fluency performance, as well as the extent to which these abilities mediated the relationship between significant psycholinguistic properties and word retrieval.

Total Number of Correct Words and Their Psycholinguistic Properties

The significantly reduced number of correct responses on animal fluency in lvPPA aligns with previous findings that individuals with lvPPA exhibit word retrieval difficulties on verbal fluency tasks (Marczinski & Kertesz, 2006; Scheffel et al., 2021). This impairment reflects the core phonological processing deficits that characterize lvPPA, which likely disrupt lexical access and word production efficiency (Gorno-Tempini et al., 2008; Henry & Gorno-Tempini, 2010). Our findings further revealed that AoA was the only psycholinguistic property that was significantly different between the lvPPA group and neurotypical controls, with individuals with lvPPA

generating words acquired earlier in life. The predominance of early-acquired words in the speech output of individuals with lvPPA may reflect the relative resilience of lexical representations acquired earlier in life, which have been proposed to benefit from more robust and long-established neural connectivity and representations (Brysbaert & Ellis, 2016). A similar pattern had been observed in Alzheimer's disease (Forbes-McKay et al., 2005; Rofes et al., 2020; Sailor et al., 2011). Given the shared underlying neuropathology between lvPPA and Alzheimer's disease (Giannini et al., 2017), it is possible that similar mechanisms underlie the reliance on early-acquired words in both conditions.

Relationship Between the Total Number of Correct Words and Their Psycholinguistic Properties

Our findings indicated that AoA predicted the total number of correct words generated in lvPPA. Specifically, individuals with lvPPA who generated a greater number of words on the animal fluency task tended to produce later-acquired words. Words acquired earlier in life tend to develop stronger representations within the mental lexicon due to the high level of neuroplasticity earlier in life, which makes them less susceptible to deterioration and thus more accessible to individuals with more impaired lexical access (Brysbaert & Ellis, 2016; Steyvers & Tenenbaum, 2005). In contrast, individuals with better preserved lexical access abilities are able to retrieve words that require greater cognitive effort and are less-entrenched in the mental lexicon, such as later-acquired words (Forbes-McKay et al., 2005).

Contributions of Phonological and Semantic Abilities to the Number of Correct Words and Their Psycholinguistic Properties

Our findings demonstrated that overall animal fluency performance in individuals with lvPPA was influenced by both phonological and semantic abilities. Previous research has primarily emphasized the role of semantics in category fluency tasks (e.g., Góni et al., 2011), and a study

has shown an indirect relationship between phonology and verbal fluency, particularly in lvPPA, where phonological deficits manifested as neologisms and increased word retrieval errors (Rofes et al., 2019). Given that verbal fluency represents a task of lexical retrieval, our results align with previous reports demonstrating that these cognitive systems interact in naming tasks (Beeson et al., 2022; Lambon Ralph et al., 2002). This interplay shows that lexical access relies on a network of semantic and phonological representations, with semantics guiding conceptual access and phonology supporting word-form retrieval (Dell et al., 1997; Jebahi & Kielar, 2024). The integration of these processes ensures efficient word retrieval, and deficits in either domain can disrupt performance.

The observed associations between psycholinguistic properties and semantic and phonological abilities provided additional insights into the mechanisms underlying lexical retrieval. With respect to frequency, the results showed a significant relationship between frequency and the integrity of both phonological and semantic systems. This association is in line with previous research suggesting that high-frequency words benefit from increased exposure and stronger lexical representations (Graves et al., 2007; Kittredge et al., 2008). From a semantic standpoint, frequent words are more deeply embedded within conceptual networks and therefore allow for robust activation via spreading activation mechanisms (Ellis & Lambon Ralph, 2000). Similarly, from a phonological perspective, frequent words may have higher resting activation, which facilitate retrieval through strengthened phonological networks (Kittredge et al., 2008).

Familiarity emerged as a factor associated with semantic abilities. Participants with lvPPA who demonstrated stronger semantic skills were more likely to generate words that were less familiar. This finding aligns with previous studies that suggest that individuals with preserved semantic knowledge can access a broader range of words, including those that are less commonly

encountered (Alario et al., 2004; Graves et al., 2007). Additionally, the role of familiarity in word retrieval has been attributed to the robustness of stored conceptual representations (Lambon Ralph et al., 1998). These findings are further supported by research on individuals with semantic impairments that has demonstrated that more familiar words tend to be more resistant to degradation (Fraser et al., 2014; Snowden et al., 1996).

Similar to frequency, AoA was associated with both semantic and phonological abilities, such that stronger abilities in these cognitive domains contributed to the production of late-acquired words. This dual association aligns with accounts that propose multiple loci for AoA effects within the lexical system (i.e., arbitrary mapping hypothesis; Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006). From a semantic perspective, early-acquired words are thought to develop richer and more interconnected conceptual representations, which makes them more accessible throughout life (Belke et al., 2005; Brysbaert & Ellis, 2016). Consequently, retrieving later-acquired words may require greater reliance on semantic control and efficiency. At the same time, AoA effects have also been attributed to phonological factors. It is thought that early-acquired words are stored as more robust phonological units, facilitating faster and more reliable retrieval (Brown & Watson, 1987). Later-acquired words, by contrast, may depend more heavily on phonological assembly processes, thereby drawing on phonological processing capacity. Taken together, the observed pattern suggests that AoA effects in lvPPA cannot be attributed solely to semantic or phonological mechanisms but rather emerge from an interaction between the richness of semantic representations and the strength of phonological encoding.

Interestingly, SND was found to be related to both semantic and phonological skills, such that better performance on these abilities contributed to the production of words with fewer semantic neighbors. This finding suggests that individuals with stronger linguistic abilities may be

able to access words that have fewer semantic competitors. Individuals with greater semantic abilities may rely on more refined selection mechanisms to efficiently retrieve words with lower semantic neighborhood density, as these words are less reliant on spreading activation from semantically related items (Mirman & Magnuson, 2008). From a phonological perspective, the retrieval of words with fewer semantic neighbors may be facilitated by stronger phonological encoding, which would allow for more precise phonological access without interference from semantically similar alternatives (Reilly & Desai, 2017).

Arousal was also found to be associated with semantic abilities. Specifically, participants with more preserved semantic skills produced words with lower arousal levels (i.e., more calming). This result is consistent with prior research in neurotypical adults where a similar pattern emerged (Ihssen et al., 2007). The authors argued that it may be due to the notion that high-arousal words can impose greater cognitive demands, requiring additional attentional and semantic resources to regulate interference (Ihssen et al., 2007). In clinical populations, the role of affective properties in word retrieval as well as their association to core cognitive skills has received limited attention (Blackett et al., 2022; Jebahi et al., 2024b). Therefore, our study provided novel insights in this regard.

Mediating Effects of Phonological and Semantic Abilities on the Relationship Between Total Number of Correct Words and Age of Acquisition

Since AoA emerged as the only significant predictor of total number of correct words generated in lvPPA, and both phonological and semantic abilities were found to influence this number and AoA, a mediation analysis was conducted to determine whether phonology and semantics mediated the relationship between AoA and total correct words. This analysis examined

both direct and indirect effects and evaluated how AoA influenced total word generation when phonological and semantic components were considered as mediators.

The results showed that phonological abilities played a partial mediating role in this relationship, whereas semantic abilities did not contribute as a mediator. Specifically, stronger phonological processing skills facilitated the retrieval of later-acquired words, which in turn supported overall word generation. However, despite this mediation, AoA retained a significant direct effect, even when phonological and semantic components were included in the model. These findings indicate that while phonology contributes the effect of AoA to word retrieval in lvPPA, AoA remains a determinant of word generation.

The partial mediation by phonology aligns with previous research that emphasized the role of phonological processing in word retrieval in individuals with lvPPA (Leyton et al., 2015; Henry & Gorno-Tempini, 2010; Mack et al., 2013). Additionally, the observed relationship suggests that individuals with lvPPA who retrieve later-acquired words tend to have relatively better preserved phonological abilities, which in turn facilitates their ability to generate more words during the animal fluency tasks. This finding further supports that early-acquired words may have more robust phonological representations, reducing the phonological processing demands required for retrieval, whereas later-acquired words require more phonological assembly (Barry et al., 2001; Brown & Watson, 1987; Kittredge et al., 2008).

The absence of a mediating role for semantic abilities suggests that, although semantics contributes to word retrieval and to AoA, it does not explain the relationship between AoA and total word generation in lvPPA. This result may reflect the fact that individuals with lvPPA experience prominent phonological deficits (Gorno-Tempini et al., 2011), making phonological factors more critical for word retrieval in fluency tasks.

Future Directions

Although the animal fluency task provided valuable insights into the lexical retrieval process, it remains a constrained and artificial measure of spontaneous word production. Examining word retrieval in more ecologically valid contexts, such as discourse, is necessary to fully understand lexical access in lvPPA. Therefore, the next study in this dissertation aimed to characterize the psycholinguistic properties of nouns and verbs produced by individuals with lvPPA in two discourse tasks: a picture description task and a storytelling narrative. This transition from word-level to discourse-level analysis aimed to provide a broader understanding of the relationship between psycholinguistic properties and lexical retrieval in lvPPA. Particularly, we identified the differences in psycholinguistic properties of nouns and verbs produced in discourse between neurotypical controls and individuals with lvPPA. Additionally, we examined how psycholinguistic properties influenced informativeness in discourse in lvPPA. This investigation provided insights into the clinical implications of studying psycholinguistic properties of lexical retrieval since effective communication does not only rely on lexical retrieval but also on the ability to convey meaningful and contextually appropriate information.

CHAPTER 4: PSYCHOLINGUISTIC CHARACTERISTICS OF LEXICAL RETRIEVAL IN DISCOURSE IN LOGOPENIC VARIANT PRIMARY PROGRESSIVE APHASIA

Introduction

Most prior research on lexical retrieval in primary progressive aphasia (PPA), including studies on the logopenic variant PPA (lvPPA), has relied on decontextualized single word naming tasks (Henry & Grasso, 2018). While these tasks provide valuable insights into naming accuracy and error patterns, they do not fully capture the demands of natural communication, where individuals must retrieve words within a broader discourse context. Discourse production tasks offer a more ecologically valid approach to assessing lexical retrieval, as they require speakers to integrate lexical retrieval with other linguistic and cognitive processes (Bryant et al., 2017). Additionally, discourse-based analyses can provide important information about how lexical retrieval relates to speech informativeness (Peach & Reuter, 2010). Informativeness is an aspect that is overlooked in word-level naming assessments but is essential for functional communication (Berndt et al., 1997; Nicholas & Brookshire, 1993).

Discourse elicitation tasks, such as picture description and storytelling, provide valuable information about how individuals retrieve and organize words in connected speech. A commonly used picture description task involves the "picnic scene" from the Western Aphasia Battery–Revised (WAB-R; Kertesz, 2007), where participants describe various elements and interactions depicted in a family picnic setting. This task enables researchers to examine different linguistic components of discourse, including lexical access, fluency, and syntactic structure (Alyahya et al., 2020; Ash et al., 2013). Similarly, storytelling tasks, such as narrating the Cinderella story, require the integration of multiple cognitive and linguistic processes, including narrative organization, temporal sequencing, and verb tense management (Saffran et al., 1989; Schnur & Wang, 2024; Stark, 2019). Storytelling tasks typically elicit more complex linguistic structures than picture

description tasks, such as the use of embedded clauses, richer vocabulary, and more cohesive discourse organization. These increased linguistic demands, in turn, place greater cognitive load on the speaker, requiring more planning, memory retrieval, and syntactic processing (Schnur & Wang, 2024; Stark, 2019).

Prior research on discourse production in lvPPA has primarily focused on macro- and micro-linguistic deficits, providing characteristics such as slow speech rate, increased disfluencies, and reduced informativeness (Ash et al., 2013; Ash & Grossman, 2015; Mack et al., 2015; Wilson et al., 2010). At the lexical level, individuals with lvPPA demonstrate a tendency to use more pronouns in place of nouns and produce fewer nouns in storytelling tasks compared to controls, all of which suggest challenges in lexical retrieval during discourse (Lavoie et al., 2021; Wilson et al., 2010). While these studies have examined aspects of speech fluency, word quantity, and syntactic structure, there remains a gap in understanding the psycholinguistic properties of words produced in discourse (Ash et al., 2006, 2013; Sajjadi et al., 2012). Given that different discourse elicitation methods may yield distinct patterns of lexical access (Chen & Chang, 2023), investigating the psycholinguistic properties of words retrieved in descriptive and narrative tasks is essential for characterizing word retrieval impairments in lvPPA.

Words vary in terms of their characteristics, and these properties play a critical role in word retrieval success. However, research on psycholinguistic influences on lexical retrieval in lvPPA has been limited. Our prior studies, as presented in the previous two chapters, have demonstrated that individuals with lvPPA exhibit impairments in retrieving words with later AoA in confrontation naming and animal fluency tasks (Jebahi et al., 2024a, 2024b). However, the psycholinguistic properties of words produced in discourse remain largely unexplored. The only study that has analyzed psycholinguistic properties in discourse in lvPPA, Zimmerer et al. (2020),

was restricted in that it only investigated frequency in nouns and used an unstructured discourse task, where participants were asked to talk about their most recent holiday. They found that individuals with lvPPA used nouns that were higher in frequency compared to controls (Zimmerer et al., 2020). Notably, no studies to date have systematically examined and compared the psycholinguistic properties of nouns and verbs produced in discourse in lvPPA, despite verbs playing a central role in sentence construction and conveying event information.

Importantly, nouns and verbs differ systematically in their psycholinguistic, semantic, and morphosyntactic properties in English, which has implications for lexical retrieval in both unimpaired and impaired populations. Nouns typically denote concrete entities and are more strongly associated with stable perceptual features, whereas verbs encode actions, events, and relations that unfold over time and often depend on argument structure and thematic role assignment (Gentner, 1982; Vigliocco et al., 2011). As a result, verbs are generally acquired later than nouns, are less imageable, and place greater demands on phonological and grammatical processing due to their inflectional morphology (e.g., tense and agreement) and their role in sentence structure (Bird et al., 2000; Pinker, 2013). These inherent differences suggest that nouns and verbs may be differentially affected in neurogenic language disorders and underscore the importance of examining their psycholinguistic properties separately within discourse contexts.

Psycholinguistic properties that affect lexical retrieval include frequency, familiarity, age of acquisition (AoA), imageability, word length, phonological neighborhood density (PND), semantic neighborhood density (SND), arousal, and valence (Alario et al., 2004; Ellis & Lambon Ralph, 2000; Jurafsky, 2003). In our two previous studies, imageability was well controlled across stimuli and both confrontation naming and category fluency tasks predominantly elicited highly imageable words (e.g., concrete nouns like objects and animals; Jebahi et al., 2024a, 2024b). In

contrast, discourse tasks provide a richer linguistic context in which both concrete and abstract words emerge, which would allow for the examination of imageability effects on lexical retrieval. Particularly, storytelling tasks, such as the Cinderella narrative, prompt the production of both highly imageable content words (e.g., *carriage*, *dress*) and more abstract lexical items (e.g., *magic*, *love*). This makes the task particularly suitable for studying the role of imageability in discourse production (Saffran et al., 1989; MacWhinney et al., 2010). Importantly, discourse tasks provide an opportunity for production of words with a wide range of psycholinguistic properties. For example, they elicit both high- and low-frequency words (e.g., *house* vs. *carriage*), familiar and less familiar items (e.g., *family* vs. *castle*), and words acquired both early and later in life (e.g., *mother* vs. *invitation*). Additionally, words differ in length and in their phonological and semantic neighborhood densities. Arousal and valence also vary across words in these discourse tasks, as speakers alternate between neutral words (e.g., *fly*) and emotionally charged words (e.g., *marry*). Given the preliminary evidence that individuals with lvPPA rely on retrieving nouns with higher frequency in discourse (Zimmerer et al., 2020), a more detailed investigation into how other psycholinguistic properties influence noun and verb production across different discourse contexts is necessary.

Additionally, understanding how psycholinguistic properties influence discourse informativeness in lvPPA is important for identifying their real-world communicative impact. Main Concept Analysis (MCA; Nicholas & Brookshire, 1993) provides a structured method for evaluating informativeness by measuring the presence and accuracy of key narrative elements. MCA identifies main concepts (MCs), which are defined as utterances that contain a subject, a main verb, and, if necessary, an object, while allowing subordinate clauses as long as only one main verb is present (Nicholas & Brookshire, 1995). Each discourse task has a predefined list of

MCs that represent the essential information needed to convey the gist of the story (Nicholas & Brookshire, 1993). A multilevel coding system assesses accuracy and completeness, classifying MCs as accurate and complete, accurate but incomplete, inaccurate but complete, or inaccurate and incomplete (Nicholas & Brookshire, 1993, 1995; Richardson & Dalton, 2016). For example, for the main concept "*the boy is flying a kite"*, an accurate and complete response would fully and accurately convey the event (e.g., *"the boy is flying a kite"*), whereas an accurate but incomplete response would preserve accuracy but omit critical information (e.g., *"the boy is flying something"*). An inaccurate but complete response would include a complete but incorrect proposition (e.g., *"the boy is flying a balloon"*), and an inaccurate and incomplete response would be both incomplete and inaccurate (e.g., *"the boy has a balloon"*).

Applying MCA to examine how psycholinguistic properties affect informativeness across different discourse contexts has important clinical implications. It can help determine whether interventions should target specific psycholinguistic properties to improve meaningful communication. For example, if lower imageability is linked to reduced informativeness, therapy may benefit from strategies that enhance retrieval of abstract words.

The present study had two primary aims. It aimed to (1) examine the psycholinguistic properties of noun and verb production in discourse tasks among individuals with lvPPA, and to (2) investigate the relationship between psycholinguistic properties and discourse informativeness in lvPPA. By examining psycholinguistic properties within naturalistic discourse tasks, this study sought to provide insights into how these word characteristics operate in an ecologically valid communication context and how they affect communication effectiveness.

Methods

Participants

Recruitment Procedures

Twenty individuals diagnosed with lvPPA were recruited as part of several ongoing research projects in the Language and Neuroimaging Research Laboratory at the University of Arizona. Participation was open to individuals across different racial, ethnic, and socioeconomic backgrounds. Recruitment sources included: the Aphasia Group at the University of Arizona's Speech, Language, and Hearing Sciences Clinic, an outpatient neurology clinic at Banner–University Medical Center, speech-language pathologists practicing in Tucson, and communications via ClinicalTrials.gov. Of the 20 individuals with lvPPA included in the current study, 11 also participated in Study 1 (Chapter 2; Jebahi et al., 2024a) and 13 overlapped with Study 2 (Chapter 3; Jebahi et al., 2024b). For all participants, data were obtained at a single time point during initial intake. Each participant provided informed consent using documents approved by the University of Arizona's Human Subjects Protection Program (**Appendix A**). The consent materials clearly outlined the nature of the study, including details of behavioral assessments. To ensure participants and their families had sufficient time to consider their participation, they were given as much time as they needed to review the consent forms. It was also emphasized that they could withdraw from the study at any point.

Nineteen neurologically healthy adults were recruited to serve as a neurotypical control group through community outreach and the Alzheimer's Prevention Registry (https://research.endalznow.org/s/) using advertisements approved by the University of Arizona's Human Subjects Protection Program. There were no restrictions regarding sex, race, ethnicity, or level of education. All control participants signed informed consent documents approved by the University of Arizona's Human Subjects Protection Program (**Appendix B**). The consent process

provided participants with detailed information about the behavioral and neuroimaging assessments involved in the study. As with the lvPPA group, control participants were provided as much time as needed to review the consent materials before agreeing to take part in the study.

Both groups completed a demographic questionnaire that gathered information on age, sex, education, handedness, languages spoken, and overall health history. Participants with lvPPA also provided additional details about their diagnosis, including symptom onset and disease progression (**Appendix C**).

Inclusion and Exclusion Criteria

To qualify for inclusion, individuals with lvPPA had to fulfill several criteria: (1) a confirmed PPA diagnosis without the presence of additional neurological or psychiatric disorders, (2) the ability to produce narratives, (3) familiarity with the Cinderella story to ensure they could narrate it, and (4) normal or corrected-to-normal hearing and vision. Individuals were excluded if they had a history of other neurological disorders, including but not limited to stroke, epilepsy, multiple sclerosis, or Parkinson's disease. Also, exclusion factors included a history of head trauma resulting in a loss of consciousness longer than five minutes and previous treatment for substance dependence. Before participating, all individuals had been diagnosed with PPA by a neurologist. Their condition was characterized by a progressive decline in language abilities, with the primary impairment affecting speech and communication in the early stages. The research team confirmed diagnosis of lvPPA based on clinical records and behavioral assessments, using the criteria established by Gorno-Tempini et al. (2011). A diagnosis of lvPPA was associated with slowed, effortful speech characterized by word-finding difficulties and/or phonemic paraphasias, as well as deficits in sentence repetition, while other linguistic and motor speech abilities remained relatively preserved.

Neurologically healthy adults were recruited as control participants without prior diagnosis of neurological or psychiatric disorders. They were native English speakers with normal or corrected-to-normal vision and hearing. Exclusion criteria were the same as those applied to the lvPPA group, including a history of significant head injury with unconsciousness for more than five minutes, prior treatment for substance use disorders, and the presence of any neurological conditions.

Both participant groups provided demographic and health history information via a self-report questionnaire, and all individuals underwent eligibility screening prior to enrollment.

Demographic Characteristics

Table 4.1 presents the demographic characteristics of both the lvPPA and neurotypical control groups. The lvPPA group comprised 20 individuals (11 females, 9 males) and the control group consisted of 19 neurologically typical adults (14 females, 5 males). On average, individuals with lvPPA were 68.45 (SD = 6.76), while control participants had a mean age of 66.71 (SD = 5.20). Participants with lvPPA had between 12 and 27 years of formal education, averaging 17.85 years (SD = 3.77), while the control group had an average of 18.03 years (SD = 3.16). No significant differences were found between the groups in terms of age, $t(37) = -.90$, $p = .376$, or education level, $t(37) = .16$, $p = .875$. Handedness was evaluated using the Edinburgh Handedness Inventory (Williams, 2010), which determines a person's dominant hand based on their preferences in everyday activities like writing and using utensils. All control participants were right-handed, whereas one individual in the lvPPA group identified as ambidextrous but functionally used their right hand. The sex distribution was similar across groups, with females comprising 55% of the lvPPA group and 74% of the control group ($\chi^2(1) = .98$, $p = .323$).

Symptom onset in the lvPPA group was reported in their 60s (M = 66.63, SD = 6.65), aligning with research indicating that PPA frequently emerges around age 65 (Mesulam et al.,

2014). Word-finding difficulties were the most commonly reported initial symptom, followed by impairments in spelling and effortful speech.

Table 4.1. *Group demographic characteristics of participants with logopenic variant primary progressive aphasia (lvPPA) with comparison to neurotypical controls (NC)*

	LvPPA (n = 20)	NC (n = 19)	t/χ^2, p
Age at testing (years)	68.45 (6.76)	66.71 (5.20)	-.90, .376
Education (years)	17.85 (3.77)	18.03 (3.16)	.16, .875
Handedness (R; A)	19; 1	19; 0	1.48, .224
Sex (F; M)	11; 9	14; 5	.98, .323

Values for age at testing and education are presented as M (SD). Values for handedness and sex are presented as counts. Independent samples t-tests were conducted for age at testing and education, and t-values reported in the last column. Chi-square tests were conducted for handedness and sex, and χ^2-values reported in the last column. R = Right-handed, A = Ambidextrous, F = Female, M = Male.

Behavioral Characteristics

A battery of assessments was administered to comprehensively evaluate cognitive and language abilities across different domains (see **Table 4.2**). Prior to testing, hearing was screened using pure-tone audiometry, and vision status was confirmed via questionnaire, ensuring normal or corrected-to-normal sensory abilities. The testing process required approximately five to six sessions for participants with lvPPA and two sessions for controls, with each session lasting about two hours. Breaks were given as needed, and participants received $10 per testing hour. Audio recordings of all sessions were stored in a Health-Insurance Portability-and-Accountability-Act-compliant electronic database. Each participant was assigned a unique numeric subject code at study enrollment, which was used on all data records, with paper copies securely stored in a locked cabinet.

Nonlinguistic Cognitive Function

The Montreal Cognitive Assessment (MoCA; Nasreddine, 2005) was used as an indicator of general cognitive status, with tasks of visuospatial function, memory, attention, naming, language, and orientation to space and time (**Table 4.2**). The control group's average score of

28.20 (*SD* = 1.36, range = 26 – 30) out of 30 fell within the normal range, while the lvPPA group had an average score of 14.68 (*SD* = 7.11, range = 6 – 28) out of 30, indicating moderate cognitive impairment.

Executive function was assessed using the number-letter trail-making switching task from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001), which requires connecting numbers and letters in alternating sequence in ascending order. The lvPPA group performed significantly below controls, $t(34) = 7.98$, $p < .001$. Verbal short-term and working memory were measured using the digit span forward and backward tasks from the Wechsler Memory Scale–Fourth Edition (WMS – 4; Wechsler, 2008), where individuals with lvPPA showed significant deficits in both tasks, $t(37) = 8.07$, $p < .001$ for digit span forward and $t(37) = 7.89$, $p < .001$ for digit span backward (see **Table 4.2**).

Symbol cancellation and complex figure copy tasks from the Kaplan-Baycrest Neurocognitive Assessment (KBNA; Leach et al., 2000) were used to evaluate visuospatial processing. In the symbol cancellation task, participants had two minutes to identify target symbols. For the complex figure task, they first copied an image and then immediately reproduced it from memory. The lvPPA group was significantly impaired in these tasks, symbol cancellation: $t(18.35) = 2.89$, $p = .010$, complex figure copy: $t(17.90) = 2.90$, $p = .010$, and complex figure recall: $t(35) = 8.34$, $p < .001$. These findings align with prior research indicating visuospatial deficits in lvPPA (Watson et al., 2018).

The Warrington Memory Test (Warrington, 1984) was used to assess recognition memory for faces and words. This task consists of encoding and recognition phases. Participants initially viewed a series of 50 faces or words and rated each as either “pleasant” or “unpleasant” to support encoding. Immediately after, they were shown pairs of faces or words and asked to select the one

they had seen before. Findings indicated significant impairment in episodic memory for faces, $t(37) = 3.60$, $p < .001$, and words, $t(11.45) = 5.63$, $p < .001$, in individuals with lvPPA (**Table 4.2**).

Nonverbal problem-solving was measured using Raven's Colored Progressive Matrices (RCPM; Raven, 1977). Since this task was introduced later in the study, data were missing for six participants with lvPPA. Individuals with lvPPA exhibited significantly lower performance compared to controls, $t(13.91) = 3.69$, $p = .002$.

Aphasia Severity

The Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007) was administered to assess overall language function in individuals with lvPPA. Participants showed language impairment, with an average Aphasia Quotient (AQ) of 81.52 ($SD = 9.72$). As expected and given the phonological processing deficits associated with lvPPA (Gorno-Tempini et al., 2008), naming was the most impaired domain, with an average accuracy of 70.24%. Repetition performance was the second most affected domain, with an average score of 75.35%.

Sensorimotor Skills

The evaluation of sensorimotor skills included tasks designed to assess auditory and visual-orthographic processing. Auditory processing was measured through the Rhyme Judgment and Minimal Pair Judgment subtests of the Arizona Phonological Battery (APB), both adapted from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA). Specifically, the Rhyme Judgment subtest corresponds to PALPA 15 and the Minimal Pair Judgment subtests correspond to PALPA 1 and PALPA 2. Participants with lvPPA demonstrated significantly lower accuracy than controls on the rhyme judgment task only, $t(19.25) = 2.86$, $p = .010$. Visual-orthographic processing was tested using PALPA subtests that evaluated letter identification (PALPA 18) and case matching (PALPA 19 and PALPA 20). Individuals with lvPPA performed comparably to controls on these visual tasks.

Speech production abilities were analyzed through word and nonword repetition. The repetition of real words was assessed through a PALPA subtest for word repetition (PALPA 11). Nonword repetition was tested using the Children's Nonword Repetition Test (CNRT), which consists of 40 nonwords with varying syllabic length and complexity. Performance on both word ($t(20.23) = 4.74$, $p < .001$) and nonword ($t(18.54) = 4.97$, $p < .001$) repetition tasks was impaired relative to controls (see **Table 4.2**). Motor speech control was examined using the Apraxia of Speech Rating Scale (ASRS; Duffy, 2006), ranging from 0 to 4 as follows: 0 = not present; 1 = detectable but infrequent; 2 = frequent but not pervasive; 3 = nearly always evident but not marked in severity; 4 = nearly always evident and marked in severity. Two participants with lvPPA showed signs of apraxia, with one exhibiting mild-to-moderate severity (score of 3) and another presenting with a mild form (score of 1) that had little impact on intelligibility.

Naming, Reading, and Spelling Abilities

On the 60-item Boston Naming Test (BNT; Kaplan et al., 1983), participants with lvPPA were significantly impaired compared to controls, with a mean accuracy of 52.67% ($SD = 29.31$) compared to 97.28 ($SD = 3.15$) in the control group, $t(19.46) = 6.77$, $p < .001$. Impairments were also observed in verbal fluency tasks from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001). Individuals with lvPPA exhibited deficits in both category, $t(34) = 13.85$, $p < .001$, and letter, $t(34) = 10.48$, $p < .001$, fluency (see **Table 4.2**).

Reading and spelling abilities were assessed using the Arizona Battery for Reading and Spelling (ABRS; Beeson et al., 2010). Control participants demonstrated near-ceiling performance. Compared to controls, individuals with lvPPA exhibited significant impairments in reading of real words and nonwords ($M = 92.63$, $t(18.11) = 3.00$, $p = .008$, and $M = 78.42$, $t(18.20) = 4.35$, $p < .001$, respectively) and written spelling of real words and nonwords ($M = 68.93$, $t(13.04) = 4.40$, $p < .001$, and $M = 57.48$, $t(16.22) = 6.17$, $p < .001$, respectively). Performance on

nonword reading and spelling tasks was poorer than on real words in individuals with lvPPA (nonwords < words reading: $t(17) = -3.65$, $p < .001$; spelling: $t(13) = -2.14$, $p = .026$), consistent with their phonological deficits (Gorno-Tempini et al., 2011). This pattern of impairment suggests disruption in the cognitive mechanisms that convert graphemes to phonemes for reading and phonemes to graphemes for spelling. These decoding and encoding mechanisms are characteristically compromised in phonological alexia and dysgraphia in lvPPA (Rapcsak et al., 2009). As a result, affected individuals may rely more heavily on lexical-semantic routes to compensate for impaired phonological processing capacity (Brambati et al., 2009).

Central Cognitive Processes for Language

To examine central cognitive processes for language, phonological, semantic, and syntactic processing abilities were assessed. Phonological processing was measured through a set of APB tasks involving phoneme deletion, blending, and segmentation. The lvPPA group demonstrated significant impairments across all tasks relative to controls, $t(19) = 5.18$, $p < .001$ for sound deletion, $t(25.51) = 6.54$, $p < .001$ for sound blending, and $t(18.83) = 8.66$, $p < .001$ for sound replacement (**Table 4.2**).

Semantic processing was assessed using four tasks evaluating receptive vocabulary and conceptual relationships between objects. The Peabody Picture Vocabulary Test – Fourth Edition (PPVT – 4) measured comprehension at the word level, the Camel and Cactus Test (CCT) assessed knowledge of object associations. Two additional PALPA subtests examined written word-to-picture matching (PALPA 48) and auditory synonym judgment (PALPA 49). Across these tasks, individuals with lvPPA showed significantly reduced accuracy in comparison to controls. The CCT was most challenging across all semantic processing tasks, with individuals with lvPPA averaging 71.64% accuracy compared to controls (92.68% accuracy). Despite these deficits, accuracy on other semantic measures remained above 85% for the lvPPA group.

Syntactic processing was evaluated through three subtests of the Northwestern Assessment of Verbs and Sentences (NAVS). The Sentence Comprehension Test (SCT) required participants to identify the correct image corresponding to an auditory sentence, whereas the Sentence Production Priming Test (SPPT) involved generating a structurally equivalent sentence based on a given model. The Argument Structure Production Test (ASPT) measured sentence formulation and correct use of subjects, objects, and verbs. The lvPPA group exhibited impairments across all syntactic measures. Sentence comprehension was mildly affected, with an average accuracy of 85.74%. The SPPT was the most difficult, with an average accuracy of 48.63%. This task is particularly reliant on phonological working memory, which is a core deficit observed in lvPPA. Performance on the ASPT (78.91%) suggests that written input may have facilitated sentence construction and further indicates that SPPT difficulties were primarily driven by phonological working memory deficits rather than impairments in sentence formulation.

Table 4.2. *Group behavioral characteristics of participants with logopenic variant primary progressive aphasia (lvPPA) with comparison to neurotypical controls (NC)*

Task, Test (score type)	*n* lvPPA, NC	LvPPA *M* (*SD*)	NC *M* (*SD*)	*t*, *p*
Nonlinguistic Cognitive Functions				
General Cognition				
Overall Cognitive Status, MoCA (/30)	20, 19	14.68 (7.11)	28.20 (1.36)	**7.50, < .001**
Executive Function				
Trail-Making Number-Letter Switching, D-KEFS (Scaled)	18, 18	3.22 (3.12)	11.56 (3.15)	**7.98, < .001**
Digit Span Forward, WMS–4 (Scaled)	20, 19	5.40 (2.93)	12.63 (2.65)	**8.07, < .001**
Digit Span Backward, WMS–4 (Scaled)	20, 19	5.90 (1.89)	11.42 (2.46)	**7.89, < .001**
Visuospatial Processing				
Symbol Cancellation, KBNA (%)	19, 19	84.29 (22.13)	99.04 (2.17)	**2.89, .010**
Complex Figure – Copy, KBNA (%)	18, 19	81.39 (23.06)	97.37 (3.86)	**2.90, .010**

Complex Figure – Immediate Recall, KBNA (Scaled)	18, 19	6.22 (3.83)	15.11 (2.56)	**8.34, < .001**
Episodic Memory				
Memory for Faces, WMT (%)	20, 19	72.20 (11.01)	84.21 (7.51)	**3.60, < .001**
Memory for Words, WMT (%)	12, 19	68.00 (17.12)	96.11 (3.09)	**5.63, < .001**
Nonverbal Problem-Solving				
Abstract Reasoning, RCPM (%)	14, 19	76.79 (17.59)	94.44 (3.82)	**3.69, .002**
Aphasia Severity				
Spontaneous Speech Content, WAB – R (%)	19, NT	88.95 (11.97)	NT	NA
Fluency, WAB – R (%)	19, NT	83.16 (11.08)	NT	NA
Comprehension, WAB – R (%)	17, NT	87.91 (9.64)	NT	NA
Repetition, WAB – R (%)	17, NT	75.35 (12.34)	NT	NA
Naming, WAB – R (%)	17, NT	70.24 (20.68)	NT	NA
Aphasia Quotient, WAB – R (%)	17, NT	81.52 (9.72)	NT	NA
Sensorimotor Skills				
Auditory Processing				
Rhyme Judgment, APB (%)	20, 19	88.63 (16.93)	99.47 (1.34)	**2.86, .010**
Minimal Pair Judgment, APB (%)	19, 19	89.74 (22.71)	98.95 (1.73)	1.76, .095
Visual-Orthographic Processing				
Letter Identification, PALPA 18 (%)	19, 19	97.37 (4.49)	99.56 (1.04)	2.08, .051
Lower-Upper Case Matching, PALPA 19 (%)	18, 19	97.65 (6.74)	100.00 (.00)	1.48, .158
Upper-Lower Case Matching, PALPA 20 (%)	18, 19	98.08 (5.94)	100.00 (.00)	1.37, .187
Speech Production				
Word Repetition, PALPA 11 (%)	19, 19	93.51 (5.22)	99.36 (1.30)	**4.74, < .001**
Nonword Repetition, CNRT (%)	19, 19	70.92 (23.02)	97.37 (2.82)	**4.97, < .001**
Motor Control, ASRS (Scaled)	20, 19	.20 (.70)	.00 (.00)	-1.29, .214
Naming, Reading, and Spelling Abilities				
Naming				
Confrontation Naming, BNT (%)	20, 19	52.67 (29.31)	97.28 (3.15)	**6.77, < .001**
Category Fluency, D-KEFS (Scaled)	18, 18	2.50 (1.89)	13.50 (2.79)	**13.85, < .001**
Letter Fluency, D-KEFS (Scaled)	18, 18	5.11 (2.81)	14.06 (2.29)	**10.48, < .001**
Reading and Spelling				

Word Reading, ABRS (%)	19, 19	92.63 (10.49)	99.87 (.57)	**3.00, .008**
Nonword Reading, ABRS (%)	19, 19	78.42 (21.02)	99.47 (1.58)	**4.35, < .001**
Word Spelling, ABRS (%)	14, 19	68.93 (25.86)	99.34 (1.13)	**4.40, < .001**
Nonword Spelling, ABRS (%)	17, 19	57.48 (27.26)	98.42 (2.39)	**6.17, < .001**
Central Cognitive Processes for Language				
Phonological Skills				
Sound Deletion, APB (%)	20, 19	64.75 (30.41)	100.00 (.00)	**5.18, < .001**
Sound Blending, APB (%)	19, 19	47.37 (27.66)	93.16 (12.93)	**6.54, < .001**
Sound Replacement, APB (%)	18, 19	37.78 (26.69)	93.68 (6.37)	**8.66, < .001**
Semantic Skills				
Single-Word Comprehension, PPVT – 4 (Scaled)	17, 19	99.29 (9.80)	120.95 (5.98)	**8.10, < .001**
Object Association, CCT (%)	20, 19	71.64 (17.00)	92.68 (3.30)	**5.43, < .001**
Written Word-to-Picture Matching, PALPA 48 (%)	17, 18	93.61 (8.28)	99.61 (.94)	**3.05, .007**
Synonym Judgment, PALPA 49 (%)	20, 18	85.33 (12.40)	97.78 (2.80)	**4.37, < .001**
Syntactic Processing				
Sentence Comprehension, NAVS (%)	18, 19	85.74 (15.63)	100.00 (.00)	**3.87, .001**
Sentence Production Priming, NAVS (%)	17, 18	48.63 (39.27)	99.44 (1.28)	**5.33, < .001**
Argument Structure Production, NAVS (%)	18, 19	78.91 (20.25)	100.00 (.00)	**4.42, < .001**

Values in bold = significant impairment relative to neurotypical controls ($p < .05$); NT = Not tested, NA = Not applicable.

Materials and Measures

Discourse Tasks

Two discourse tasks, a picture description and a storytelling task, were administered to elicit spoken language samples from participants. The picture description task required participants to describe the picnic scene from the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2007), as shown in **Figure 4.1**. This task was designed to facilitate connected speech production in a contextually supported setting. The presence of visual stimulus (i.e., the picnic scene) provided participants with support for word retrieval and minimized memory load for discourse production. Additionally, the scene depicted familiar activities and objects, which may encourage spontaneous descriptions of actions, objects, and relationships. The vocabulary demands of the picnic scene

included both common (e.g., *tree*, *book*) and less frequently encountered objects (e.g., *dock*, *fishing rod*). This allows for an analysis of words with diverse psycholinguistic properties.

Figure 2.1. *Picnic scene of Western Aphasia Battery – Revised for picture description task*

For the storytelling task, participants narrated the story of Cinderella. To initiate the task, the examiner inquired whether the participant was familiar with the story. If they confirmed familiarity, they proceeded with the task. Participants were then given a wordless picture book depicting the important events from the narrative. After reviewing the images, the book was removed from view, and participants were asked to retell the story from memory. This narrative task has been widely used in discourse-based research, particularly with populations with neurogenic and neurodegenerative language disorders. The Cinderella story is included in established discourse databases such as AphasiaBank (Forbes et al., 2012) and DementiaBank (Lanzi et al., 2023). Additionally, prior research (e.g., Cummings, 2019; Bird & Franklin, 1996)

has highlighted the value of this task in eliciting words with diverse psycholinguistic characteristics.

These two discourse tasks complemented one another by offering different linguistic demands: the picture description task captured functionally relevant, everyday language use, while the storytelling task provided a broader narrative structure with opportunities for retrieval of more diverse lexical items.

Psycholinguistic Properties

The psycholinguistic properties of nouns and verbs produced in both discourse tasks were extracted for both the lvPPA and neurotypical control group. Values for these properties were extracted from the South Carolina Psycholinguistic Metabase (SCOPE; Gao et al., 2022). Frequency, which was defined by how often a word is used in English, was sourced from Brysbaert & New (2009). Familiarity, reflecting the ease with which a word's concept is recognized, was obtained from Scott et al. (2019). Age of acquisition (AoA), which represents the typical age at which a word is learned, was derived from Kuperman et al. (2012). Imageability, which represented how easily a word evokes a mental image, was taken from Scott et al. (2019). Word length, defined as the number of phonemes in a word, was extracted from the English Lexicon Project (ELP; Balota et al., 2007). Phonological neighborhood density (PND), which quantifies the number of words differing by a single phoneme, was also obtained from ELP (Balota et al., 2007). Semantic neighborhood density (SND), represented as the number of semantically related words, was sourced from Shaoul & Westbury (2010). Arousal reflected the level of emotional activation linked to a word and ranged from 0 (calming) to 1 (highly arousing) (Mohammad, 2018). Valence indicated the emotional tone of a word, with scores from 0 (negative) to 1 (positive) (Mohammad, 2018).

Many of these psycholinguistic properties are known to be interrelated. Frequency, familiarity, AoA, SND are typically highly correlated, such that more frequent words tend to be rated as more familiar, acquired earlier, and occur in denser semantic neighborhoods (Brysbaert & Ellis, 2016; Kuperman et al., 2012; Scott et al., 2019; Shaoul & Westbury, 2010). Similarly, word length and PND are often negatively correlated: shorter words tend to have denser phonological neighborhoods (Vitevitch & Luce, 2005). Valence and arousal may also show a correlation depending on the nature of the task and stimuli, though this relationship is not linear. For example, high-arousal words can be either highly positive (e.g., *celebrate*) or highly negative (e.g., *scream*) (Mohammad, 2018; Citron et al., 2012). In contrast, imageability is not always correlated with most other properties. For instance, low-imageability words can be very frequent (e.g., *thing*, *do*) or relatively infrequent (e.g., *justice*, *hypothesis*), while highly imageable words can also range from frequent (e.g., *dog*, *house*) to infrequent (e.g., *tornado*, *giraffe*) (Paivio, 1991; Westbury et al., 2013). This suggests that imageability captures a distinct aspect of lexical representation.

Importantly, the strength and nature of the relationships between psycholinguistic properties can vary by part of speech (nouns and verbs) and task demands. For example, frequency and AoA tend to be more strongly correlated for nouns (e.g., *house, car*) (Bonin et al., 2004). In contrast, this relationship is weaker for verbs, which may be acquired later despite sometimes being highly frequent (e.g., *explain, believe*) (Colombo & Burani, 2002; Kuperman et al., 2012). Task demands further modulate these interrelationships. In picture-naming and description tasks, imageability and frequency often align, since visually salient objects (e.g., *dog*, *chair*) are both highly imageable and frequent, whereas abstract or relational verbs (e.g., *think*, *decide*) may be frequent but low in imageability (Bird et al., 2001). In contrast, during narrative tasks, speakers

often produce a wider range of lower frequency but highly imageable nouns (e.g., *castle*, *pumpkin*) which reduces the correlation between imageability and frequency.

Informativeness: Main Concepts Analysis

We used MCA to quantify discourse informativeness in both discourse tasks. MCA is a structured discourse analysis method that evaluates the accuracy and completeness of essential concepts conveyed in spoken narratives (Nicholas & Brookshire, 1993, 1995; Richardson & Dalton, 2016). It provides a systematic measure of informativeness by quantifying the extent to which a speaker successfully communicates the fundamental elements of a discourse task. Importantly, MCA is an ecologically valid metric, as it has been shown to closely align with listener ratings of communication ability and conversational effectiveness (Ross & Wertz, 1999).

MCA requires a predetermined set of Main Concepts (MCs) for each discourse task. These MCs are typically identified through norming procedures with unimpaired control groups. For the Cinderella narrative, we used an existing set of normed MCs published by Richardson and Dalton (2016). However, because no MCs had previously been established for the picnic scene, we followed the same methodological framework to develop a new set specifically for this study.

To establish MC norms for the picnic scene, we analyzed discourse samples from 49 neurologically healthy adults including 17 from the Language and Neuroimaging Research Laboratory and 32 from AphasiaBank (Olness et al., 2011). Two trained research assistants independently extracted relevant concepts (RCs) from these narratives. Each RC contained a subject, one main verb, and, when applicable, an object. The presence or absence of each RC was coded in binary form (1 = produced; 0 = not produced). Interrater agreement was high (87.17%), and any discrepancies were resolved through discussion. For instance, one rater identified “there is a house with the car in the driveway” as a single RC while the other rater split it into two RCs (one for the house and one for the car) and agreement was achieved by listing them as separate

RCs. After finalizing the RC list, we calculated production frequencies across all participants. Following the threshold used by Richardson and Dalton (2016), any RC produced by at least 33% of the sample (i.e., at least 16 out of 49 participants) was designated as a MC. This process yielded 18 MCs for the picnic scene.

MCA was then applied to each participant's discourse sample. We used the MCA scoring system (Nicholas & Brookshire, 1993; Richardson & Dalton, 2016) to evaluate the informativeness of each participant's narrative by assigning a score to each MC based on its accuracy and completeness. Each MC was scored using one of five possible codes: absent (AB), accurate and complete (AC), accurate but incomplete (AI), inaccurate but complete (IC), and inaccurate and incomplete (II). To calculate an overall informativeness score for each participant, we applied the following weighted formula: MCA Score = (3 × AC) + (2 × AI) + (2 × IC) + (1 × II).

Procedure

Participants completed both discourse tasks in a quiet environment, and their responses were audio-recorded for transcription and analysis. The picture description task involved presenting participants with the picnic scene image from the WAB – R (see **Figure 4.1**; Kertesz, 2007). Participants were instructed to describe the image using complete sentences. The other task required participants to retell the Cinderella story. Before this narration, participants reviewed a wordless picture book of the story to aid recall. Following AphasiaBank procedures (Forbes et al., 2012), the examiner first confirmed the participant's familiarity with the story. If they were familiar, they examined the wordless book for however much time they needed before it was removed, after which they were asked to retell the story in as much detail as possible. If a participant had difficulty continuing, the examiner provided minimal prompts (e.g., "Could you

tell me more?"). The task concluded when the participant indicated they had finished their narrative.

All recorded discourse samples were transcribed verbatim and checked for accuracy. Transcriptions were initially generated using Whisper AI, an automated speech recognition model developed by OpenAI, which has been shown to be reliable for transcribing speech samples from individuals with aphasia (Sanguedolce et al., 2024). Nonetheless, given that automated transcriptions may contain errors, all generated transcriptions were manually reviewed and corrected to ensure fidelity. Whisper AI transcripts were found to be 99.43% accurate. Whisper AI maintains strict privacy standards, and all audio files were automatically deleted after transcription to uphold participant confidentiality.

From the transcribed discourse, nouns (extracted in singular form) and verbs (extracted in stem form, excluding auxiliary verbs) were identified. This process was done by the author of this dissertation and 20% of the transcripts underwent another noun and verb extraction by a trained research assistant in the Language and Neuroimaging Research Laboratory. The agreement between both raters was 94.28%. Psycholinguistic properties for each extracted noun and verb, including frequency, familiarity, AoA, imageability, word length, PND, SND, valence, and arousal, were obtained using SCOPE (Gao et al., 2022). For each participant, mean values were computed for each psycholinguistic property separately for nouns and verbs.

MCA was also conducted on each participant's discourse production to evaluate informativeness. For the Cinderella story, scoring was on the established MC norms from Richardson and Dalton (2016). For the picnic scene, MCA was based on the set of MCs derived through our norming procedure. Each narrative was scored using a structured coding system that captured the accuracy and completeness of each MC (see above). MC coding for both discourse

tasks was conducted by the author of this dissertation. Additionally, 20% of the transcripts were independently coded by a trained research assistant in the Language and Neuroimaging Research Laboratory. Interrater agreement was high, with 95.29% agreement for the Cinderella task and 95.56% for the picnic scene description. Discrepancies were solved with the director of the Language and Neuroimaging Research Laboratory and the chair of this dissertation, Dr. Aneta Kielar. Final scores based on the MCA weighted formula were then used to compute an overall informativeness score per task for each participant.

Data Analyses

All statistical analyses for this study were carried out using SPSS version 29.0.2.0. Independent samples *t*-tests were conducted to compare the total number of nouns and verbs produced in each discourse task between groups. This analysis examined whether individuals with lvPPA exhibited reduced lexical retrieval (nouns and verbs separately) compared to controls in each of the tasks.

We used repeated measures multilevel mixed-effects models to examine differences in the psycholinguistic properties (i.e., frequency, familiarity, AoA, imageability, word length, PND, SND, valence, and arousal) of nouns and verbs across discourse tasks between individuals with lvPPA and control participants. These models accounted for the hierarchical structure of the data, with repeated measures nested within participants. Participants were included as Level 2 random effects, while discourse task (picture description vs. storytelling) and part of speech (noun vs. verb) were included as Level 1 fixed effects. To account for potential differences in lexical retrieval across participants, the total number of nouns and verbs produced was included as a covariate in all models. Additionally, commonly interrelated psycholinguistic properties (e.g., frequency, familiarity, AoA, and SND) were included as covariates for each outcome variable based on a

priori theoretical and empirical evidence, as described in the *Psycholinguistic Properties* text above.

Because our study examined multiple parts of speech (nouns and verbs) across different discourse tasks (picture description and storytelling), the relationships among psycholinguistic properties could not be represented by a single correlation structure in our dataset. Each psycholinguistic property had distinct values depending on participant group (lvPPA vs. controls), task type, and part of speech. As a result, calculating a single within-sample correlation matrix would obscure group-, task-, and category-specific patterns of shared variance. To address this, separate correlation matrices were computed for each combination of discourse task and part of speech: nouns in the picnic picture description, verbs in the picnic picture description, nouns in the Cinderella storytelling task, and verbs in the Cinderella storytelling task across both groups. Pearson's correlation coefficients were calculated to characterize the interrelationships among psycholinguistic properties within each linguistic context. These matrices were used descriptively to document task- and category-specific patterns of association. To guide covariate selection, we relied on established theoretical and empirical evidence from prior research to identify commonly interrelated psycholinguistic properties and include them as covariates in our models. This approach ensured that we accounted for known sources of shared variance while avoiding data-driven decisions that could obscure true effects or be inconsistent across subcategories. Accordingly, covariate selection was guided by consistent findings in the literature (e.g., strong interrelationships among frequency, familiarity, AoA, and SND; inverse associations between word length and PND; weak or inconsistent associations involving imageability, valence, and arousal). By adopting this a priori strategy, we aimed to maximize interpretability and replicability of our models while appropriately controlling for psycholinguistic overlap that could otherwise

confound effects of interest. Three interaction effects were tested: (1) group × task, (2) group × part of speech, and (3) group × task × part of speech. These analyses aimed to identify differences in psycholinguistic properties between groups and to explore patterns of noun and verb production across tasks in lvPPA. Models were fitted to the data, and hypothesis tests were conducted for the main effects of group as well as its interactions with discourse task and part of speech. Type III tests of fixed effects were used to evaluate significance, and pairwise comparisons were performed for significant interactions to further investigate group and condition differences. Corrections for multiple comparisons were performed using the Bonferroni method to control for Type I error. All reported *p* values reflect these Bonferroni-adjusted values as calculated in SPSS.

To investigate whether psycholinguistic properties influenced informativeness, multiple linear regression analyses were conducted. Informativeness was quantified using MCA, for each discourse task, and psycholinguistic properties of nouns and verbs (average) were entered as predictors in models for individuals with lvPPA. These analyses assessed the extent to which different psycholinguistic properties contributed to the informativeness of discourse production in lvPPA.

Results

Descriptive Results

To characterize the profiles of lexical production across groups, descriptive statistics were calculated for the total number of nouns and verbs produced by participants with lvPPA and unimpaired controls. Independent samples *t*-tests were conducted to examine group differences in lexical retrieval during both picnic scene picture description and Cinderella storytelling tasks by comparing the proportion of nouns and verbs produced by individuals with lvPPA and control participants. The results are summarized in **Table 4.3**.

Table 4.3. *Descriptive statistics and results of independent samples t-test comparing proportions of nouns and verbs (out of total number of words) produced for individuals with logopenic primary progressive aphasia (lvPPA) and neurotypical controls (NC) across tasks*

Task	POS	LvPPA *M* (*SD*)	NC *M* (*SD*)	Mean Difference	*t, p*
Picnic	Nouns	.14 (.05)	.20 (.05)	-.06	-3.45, .002
	Verbs	.07 (.02)	.09 (.03)	-.02	-2.58, .014
Cinderella	Nouns	.07 (.02)	.09 (.02)	-.02	-3.93, < .001
	Verbs	.07 (.02)	.09 (.02)	-.02	-3.02, .005

For the picnic scene task, individuals with lvPPA produced a significantly lower proportion of nouns (M = .14, SD = .05) compared to controls (M = .20, SD = .05), $t(34) = -3.45$, p = .002. For verb proportions, a similar pattern was observed. The lvPPA group produced significantly fewer verbs (M = .07, SD = .02) than controls (M = .09, SD =.03), $t(34) = -2.58$, p = .014. See **Table 4.4.**

For the Cinderella story, individuals with lvPPA also produced a significantly lower proportion of nouns (M = .07, SD = .02) than controls (M = .09, SD = .02), $t(37) = -3.93$, $p < .001$. Similarly, individuals with lvPPA produced a significantly lower proportion of verbs (M = .07, SD = .02) compared to controls (M = .09, SD = .02), $t(37) = -3.02$, p = .005 (**Table 4.4**).

Table 4.4. *Descriptive statistics of nouns and verbs and their psycholinguistic properties in two discourse tasks for individuals with logopenic primary progressive aphasia (lvPPA) and neurotypical controls (NC)*

		Picnic scene picture description				Cinderella storytelling			
		Nouns		Verbs		Nouns		Verbs	
Group		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
LvPPA (*n* = 20)	Frequency	3.76	.32	4.64	.43	3.77	.39	4.63	.36
	Familiarity	6.33	.19	6.23	.15	6.16	.24	6.15	.18
	AoA	4.28	.42	4.24	.44	4.69	.65	4.63	.51
	Imageability	6.29	.28	4.85	.73	5.98	.44	4.09	.38
	Word length	3.88	.49	2.93	.28	4.07	.65	3.11	.27
	PND	19.15	5.46	32.17	5.86	16.78	4.82	30.65	5.48
	SND	.64	.03	.66	.02	.64	.03	.68	.01
	Arousal	.37	.03	.43	.05	.41	.05	.47	.03

	Valence	.69	.04	.66	.05	.70	.04	.66	.05
NC (*n* = 19)	Frequency	3.37	.18	4.07	.23	3.26	.13	4.14	.028
	Familiarity	6.20	.14	6.02	.11	5.99	.11	6.01	.09
	AoA	4.75	.39	4.62	.29	5.29	.44	5.12	.58
	Imageability	6.24	.14	5.08	.34	5.96	.33	4.25	.31
	Word length	4.19	.24	3.20	.26	4.56	.25	3.51	.39
	PND	18.11	1.67	29.30	3.48	14.61	2.13	24.90	4.31
	SND	.60	.02	.65	.01	.59	.01	.65	.02
	Arousal	.37	.03	.47	.03	.40	.02	.50	.03
	Valence	.66	.03	.64	.03	.68	.02	.62	.04

Note. AoA = Age of acquisition; PND = Phonological neighborhood density; SND = Semantic neighborhood density

Correlation Matrices

Tables 4.5a – 4.5h present correlation matrices for psycholinguistic properties of words produce, stratified by group (individuals with lvPPA vs. neurotypical controls), discourse task (picnic picture description vs. Cinderella storytelling) and part of speech (nouns vs. verbs). Across correlation matrices stratified by group, discourse task, and part of speech, several stable interrelationships emerged among psycholinguistic properties. Frequency, familiarity, AoA, and SND consistently formed a tight cluster across conditions. Word length showed a reliable inverse relationship with PND. In contrast, imageability, arousal, and valence demonstrated greater variability across tasks and word classes. Despite these shared patterns, notable differences emerged across groups, tasks, and parts of speech. For example, the relationships between frequency, familiarity, AoA, and SND, while directionally preserved, were weaker and more fragmented in lvPPA compared to controls. Additionally, in the Cinderella storytelling task, arousal showed relationships with AoA and imeageability. In the picnic scene picture description task, arousal was largely uncorrelation with any lexical properties. In terms of part of speech, the relationship between AoA and imageability was strong and negative in nouns, but weak, inconsistent, or absent in verbs.

Table 4.5a. *Correlation matrix of psycholinguistic properties for nouns produced by individuals with logopenic primary progressive aphasia (lvPPA) in the picnic picture description*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.41	1							
AoA	-.36	-.77***	1						
Imageability	-.19	.39	-.28	1					
Word Length	-.49*	-.49*	.49*	.02	1				
PND	.23	.17	-.31	-.20	-.69**	1			
SND	.75***	.76***	-.59**	.03	-.66**	.27	1		
Arousal	-.25	-.43	.15	-.27	.34	.16	-.36	1	
Valence	-.06	.18	-.37	.15	.32	-.49*	.03	.172	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5b. *Correlation matrix of psycholinguistic properties for verbs produced by individuals with logopenic primary progressive aphasia (lvPPA in the picnic picture description*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.41	1							
AoA	-.09	-.70**	1						
Imageability	-.77***	-.11	-.33	1					
Word Length	-.66**	-.73***	.38	.39	1				
PND	.43	.47*	-.12	-.19	-.79***	1			
SND	.78***	.49*	-.13	-.73***	-.65**	.38	1		
Arousal	-.37	-.44	.10	.25	.43	-.50*	-0.19	1	
Valence	.39	.36	-.31	-.43	-.27	-.04	.58**	.08	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5c. *Correlation matrix of psycholinguistic properties for nouns produced by neurotypical controls in the picnic picture description*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.75***	1							
AoA	-.81***	-.70**	1						
Imageability	.19	.43	-.54*	1					
Word Length	-.58*	-.51*	.54*	-.39	1				
PND	.40	.26	-.26	.09	-.79***	1			
SND	.77***	.61*	-.48	.01	-.38	.34	1		
Arousal	.64**	.36	-.34	-.25	-.12	.05	.35	1	
Valence	.53*	.37	-.47	-.13	-.02	.07	.50*	.46	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5d. *Correlation matrix of psycholinguistic properties for verbs produced by neurotypical controls in the picnic picture description*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.20	1							
AoA	-.86***	-.31	1						
Imageability	-.56*	.27	.33	1					
Word Length	-.89***	-.02	.78***	.48	1				
PND	.39	-.40	-.41	-.12	-.65**	1			
SND	.65**	-.10	-.43	-.21	-.59*	.30	1		
Arousal	.03	.05	-.06	-.22	-.07	.09	.02	1	
Valence	.16	.10	-.18	.16	-.02	-.14	.30	-.21	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5e. *Correlation matrix of psycholinguistic properties for nouns produced by individuals with logopenic primary progressive aphasia (lvPPA in the Cinderella storytelling*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.83***	1							
AoA	-.83***	-.78***	1						
Imageability	-.23	.13	.02	1					
Word Length	-.87***	-.71***	.72***	.15	1				
PND	.50*	.62**	-.46*	.29	-.70**	1			
SND	.80***	.49*	-.64**	-.38	-.72***	.30	1		
Arousal	-.03	.02	.02	.19	-.07	-.17	-.01	1	
Valence	.14	.02	-.28	.13	.02	-.20	.22	0.18	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5f. *Correlation matrix of psycholinguistic properties for verbs produced by individuals with logopenic primary progressive aphasia (lvPPA in the Cinderella storytelling*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.53*	1							
AoA	-.38	-.43	1						
Imageability	-.69***	-.48*	.09	1					
Word Length	-.61**	-.31	.42	.20	1				
PND	.41	.23	-.36	-.02	-.84***	1			
SND	.46*	-.03	.16	-.23	-.49*	.19	1		
Arousal	-.42	-.57**	.26	.51*	.24	-.31	.04	1	
Valence	-.05	.05	-.44	.40	-.38	.56*	.09	.06	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5g. *Correlation matrix of psycholinguistic properties for nouns produced by neurotypical controls in the Cinderella storytelling*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.11	1							
AoA	-.32	-.39	1						
Imageability	-.20	.30	-.75***	1					
Word Length	-.60**	-.41	.53*	-.18	1				
PND	.34	.28	-.39	.19	-.80***	1			
SND	.90***	.22	-.18	-.24	-.43	.24	1		

Arousal	0.20	-.75***	.46*	-.59**	.46*	-.35	.12	1	
Valence	0.11	0.14	-.49*	.47*	.03	-.19	.07	-.14	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Table 4.5h. *Correlation matrix of psycholinguistic properties for verbs produced by neurotypical controls in the Cinderella storytelling*

	Frequency	Familiarity	AoA	Imageability	Word Length	PND	SND	Arousal	Valence
Frequency	1								
Familiarity	.73***	1							
AoA	-.92***	-.84***	1						
Imageability	.25	.26	-.47*	1					
Word Length	-.86***	-.64**	.90***	-.51*	1				
PND	.82***	.49*	-.77***	.43	-.88***	1			
SND	.87***	.63**	-.74***	-.01	-.67**	.67**	1		
Arousal	-.56*	-.40	.59**	-.28	.61**	-.45	-.60**	1	
Valence	.20	.42	-.26	.15	-.23	.16	.21	-.27	1

Values represent Pearson's correlation coefficient *r*; Asterisks denote significant Pearson's correlations at $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density

Linear Mixed Effects Models Results

The main effects and interactions derived from the linear mixed-effects models examining psycholinguistic properties of nouns and verbs across groups, tasks, and parts of speech, are shown in **Table 4.6a**. This includes effects for group, group × task, group × part of speech, and the three-way interaction (group x task x part of speech). **Table 4.6b** complements these findings by providing descriptive results from significant pairwise comparisons, showing the directions of significant main effects and interactions.

Table 4.6a. *Significant main effects and interactions for psycholinguistic properties of nouns and verbs in discourse elicitation tasks*

Psycholinguistic property	Main effect: Group			Interaction: Group x task			Interaction: Group x POS			Interaction: Group x task x POS		
	df1, df2	*F*	*p*	*df1, df2*	*F*	*p*	*df1, df2*	*F*	*p*	*df1, df2*	*F*	*p*
Frequency	1, 112.25	14.35	< .001	2, 67.09	9.77	< .001	2, 116.54	61.85	< .001		n.s.	
Familiarity		n.s.		2, 80.60	3.77	.027	2, 107.57	16.57	< .001	2, 64.82	8.47	< .001
AoA		n.s.		2, 59.67	10.31	< .001	2, 128.66	6.43	.002		n.s.	
Imageability	1, 89.76	4.25	.042	2, 53.30	37.58	< .001	2, 52.23	359.21	< .001	2, 52.27	8.44	< .001
Word length	1, 100.82	18.56	< .001	2, 59.54	4.09	.022	2, 108.43	29.68	< .001		n.s.	
PND		n.s.		2, 68.39	3.68	.030	2, 128.30	21.95	< .001		n.s.	
SND	1, 134.33	4.34	.039		n.s.		2, 126.24	18.44	< .001		n.s.	
Arousal		n.s.		2, 66.47	17.73	< .001	2, 64.59	137.07	< .001		n.s.	
Valence		n.s.			n.s.		2, 66.56	30.42	< .001		n.s.	

Note. AoA = Age of acquisition; PND = Phonological neighborhood density; SND = Semantic neighborhood density; n.s. = Not significant. The total number of nouns and verbs produced was included as a covariate in all models.

Table 4.6b. *Results of pairwise comparisons for psycholinguistic properties of nouns and verbs in discourse elicitation tasks*

Psycholinguistic property	Main effect: Group	Interaction: Group x Discourse elicitation task	Interaction: Group x POS	Interaction: Group x Discourse elicitation task x POS
Frequency	lvPPA > NC	Cinderella: lvPPA > NC Picnic: lvPPA > NC NC: Cinderella > picnic	Verbs: lvPPA > NC lvPPA: verbs > nouns NC: verbs > nouns	n.s.
Familiarity	n.s.	Picnic: lvPPA > NC lvPPA: Picnic > Cinderella	Verbs: lvPPA > NC lvPPA: Nouns > Verbs NC: Nouns > Verbs	NC Nouns: Picnic > Cinderella lvPPA Nouns: Picnic > Cinderella NC Picnic: nouns > verbs lvPPA Picnic: nouns > verbs

				NC Cinderella: nouns > verbs
AoA	n.s.	lvPPA: Cinderella > Picnic NC: Cinderella > Picnic	lvPPA: Verbs > Nouns NC: Verbs > Nouns	n.s.
Imageability	NC > lvPPA	lvPPA: Picnic > Cinderella NC: Picnic > Cinderella	Verbs: NC > lvPPA lvPPA: Nouns > Verbs NC: Nouns > Verbs	lvPPA Picnic: nouns > verbs NC Picnic: nouns > verbs lvPPA Cinderella: nouns > verbs NC Cinderella: nouns > verbs lvPPA Nouns: Picnic > Cinderella NC Nouns: Picnic > Cinderella lvPPA Verbs: Picnic > Cinderella NC Verbs: Picnic > Cinderella Cinderella Verbs: NC > lvPPA
Word length	NC > lvPPA	Picnic: NC > lvPPA Cinderella: NC > lvPPA NC: Cinderella > Picnic	Nouns: NC > lvPPA Verbs: NC > lvPPA lvPPA: Nouns > Verbs NC: Nouns > Verbs	n.s.
PND	n.s.	NC: Picnic > Cinderella	Nouns: NC > lvPPA Verbs: lvPPA > NC lvPPA: Verbs > Nouns NC: Verbs > Nouns	n.s.
SND	lvPPA > NC	n.s.	Nouns: lvPPA > NC NC: Verbs > Nouns	n.s.
Arousal	n.s.	lvPPA: Cinderella > Picnic NC: Cinderella > Picnic	lvPPA: Verbs > Nouns NC: Verbs > Nouns Verbs: NC > lvPPA	n.s.
Valence	n.s.	n.s.	lvPPA: Nouns > Verbs	n.s.

	NC: Nouns > Verbs

Note. AoA = Age of acquisition; PND = Phonological neighborhood density; SND = Semantic neighborhood density; n.s. = Not significant.

Frequency

The linear mixed-effect model revealed significant differences in the frequency of words produced across groups, with several interactions. This model controlled for total number of nouns and verbs produced, familiarity, AoA, and SND.

A significant *group by task* interaction emerged, $F(2, 67.09) = 9.77$, $p < .001$, such that that across both tasks, individuals with lvPPA produced higher-frequency words than controls (e.g., lvPPA: *food*, *run*; controls: *basket*, *chase*). The difference between lvPPA and controls was significant in the picnic picture description (lvPPA: $M = 4.00$, $SE = .05$; control: $M = 3.83$, $SE = .02$), $F(1, 50.25) = 10.75$, $p = .002$, and in the Cinderella storytelling task (lvPPA: $M = 4.04$, $SE = .04$; control: $M = 3.94$, $SE = .02$), $F(1, 58.07) = 5.64$, $p = .021$. Pairwise within-group comparisons showed that control participants used more frequent words during Cinderella storytelling than picnic scene picture description (Cinderella: $M = 3.94$, $SE = .02$; picnic: $M = 3.83$, $SE = .02$), $F(1, 67.05) = 19.42$, $p < .001$. This pattern was not observed in the lvPPA group, such that individuals with lvPPA produced words with similar frequency in both narrative tasks, $p = .445$.

A significant interaction for *group by part of speech* was also observed, $F(2, 116.54) = 61.95$, $p < .001$. Specifically, the lvPPA group produced verbs with higher-frequency relative to controls (lvPPA: $M = 4.32$, $SE = .05$; controls: $M = 4.07$, $SE = .02$), $F(1, 50.73) = 23.83$, $p < .001$. Both groups produced higher frequency verbs compared to nouns: controls (verbs: $M = 4.07$, $SE = .02$; nouns: $M = 3.71$, $SE = .03$), $F(1, 100.25) = 49.73$, $p < .001$; lvPPA (verbs: $M = 4.32$, $SE = .05$; nouns: $M = 3.72$, $SE = .03$), $F(1, 76.28) = 94.88$, $p < .001$.

Familiarity

A mixed-effects model was conducted to examine differences in the familiarity of nouns and verbs produced during the Cinderella storytelling and picnic scene picture description

discourse tasks between individuals with lvPPA and control participants, accounting for relevant covariates (total number of nouns and verbs produced, frequency, AoA, and SND).

A significant interaction between *group by task* was observed, $F(2, 80.60) = 3.77$, $p = .027$. Specifically, familiarity of words produced during the picnic task was significantly higher for individuals with lvPPA than for controls (lvPPA: $M = 6.20$, $SE = .02$; controls: $M = 6.13$, $SE = .02$), $F(1, 77.10) = 4.73$, $p = .033$. For instance, participants with lvPPA more often produced highly familiar words such as *tree* and *sit*, whereas controls included relatively less familiar terms such as *blanket* and *stroll*. No significant group differences were found in the Cinderella task ($p = .880$). Pairwise within-group comparisons revealed that individuals with lvPPA produced words with significantly higher familiarity in the picnic task than in the Cinderella story (picnic: $M = 6.20$, $SE = .02$; Cinderella: $M = 6.11$, $SE = .03$), $F(1, 71.32) = 6.89$, $p = .011$. This difference was not significant in the control group ($p = .274$).

There was also a significant *group by part of speech* interaction, $F(2, 107.57) = 16.57$, $p < .001$. Test of this interaction revealed that while no group differences were observed in the familiarity of nouns ($p = .878$), the lvPPA group produced verbs that were significantly more familiar than those produced by controls (lvPPA: $M = 6.08$, $SE = .03$; controls: $M = 6.02$, $SE = .02$), $F(1, 74.28) = 4.25$, $p = .043$. For example, individuals with lvPPA produced high-familiarity verbs such as *run, drink, play*, while controls produced less familiar verbs such as *chase, sip, gather*. Within-group comparisons showed that both groups produced more familiar nouns than verbs. For controls, nouns were significantly more familiar than verbs (nouns: $M = 6.22$, $SE = .03$; verbs: $M = 6.02$, $SE = .02$), $F(1, 115.71) = 32.39$, $p < .001$. A similar pattern was observed in the lvPPA group, with nouns produced rated as more familiar than verbs (nouns: $M = 6.23$, $SE = .03$; $M = 6.08$, $SE = .03$), $F(1, 76.01) = 11.69$, $p = .001$.

A significant three-way interaction (*group by task by part of speech*), $F(2, 64.82) = 8.47$, $p < .001$ emerged. Specifically, noun familiarity differed by task for both groups. Controls produced more familiar nouns in the picnic task than in Cinderella (picnic: $M = 6.28$, $SE = .03$; Cinderella: $M = 6.16$, $SE = .03$), $F(1, 41.14) = 12.05$, $p = .001$. The same was true for participants with lvPPA (picnic: $M = 6.29$, $SE = .03$; Cinderella: $M = 6.17$, $SE = .04$), $F(1, 36.21) = 6.95$, $p = .012$. Both groups also showed significant noun–verb familiarity differences in the picnic task such that nouns were significantly more familiar than verbs: controls (nouns: $M = 6.28$, $SE = .03$; verbs: $M = 5.99$, $SE = .03$), $F(1, 68.81) = 45.85$, $p < .001$; lvPPA (nouns: $M = 6.29$, $SE = .03$; verbs: $M = 6.10$, $SE = .03$), $F(1, 41.92) = 14.93$, $p < .001$. In the Cinderella narrative, the noun–verb difference was significant for controls (nouns: $M = 6.16$, $SE = .03$; verbs: $M = 6.05$, $SE = .02$), $F(1, 74.70) = 7.31$, $p = .008$, but not for lvPPA ($p = .062$). A group difference emerged for verbs in the picnic task, with higher familiarity in the lvPPA group compared to controls (lvPPA: $M = 6.10$, SE = .03; controls: $M = 5.99$, SE = .03), $F(1, 44.51) = 8.90$, $p = .005$.

Age of Acquisition

A mixed-effects model was conducted to examine differences in AoA of nouns and verbs across the two discourse tasks (Cinderella storytelling and picnic picture description) and across nouns and verbs between individuals with lvPPA and control participants. The model controlled for total number of nouns and verbs and relevant psycholinguistic covariates (frequency, familiarity, and SND).

Results revealed a significant interaction of *group by task*, $F(2, 59.67) = 10.31$, $p < .001$. Specifically, control participants produced words with significantly later AoA in the Cinderella storytelling task than in the picnic picture description task (Cinderella: $M = 4.80$, $SE = .06$; picnic: $M = 4.52$, $SE = .04$), $F(1, 56.04) = 17.09$, $p < .001$. Similarly, participants with lvPPA produced later-acquired words in the Cinderella task compared to the picnic picture description task

(Cinderella: $M = 4.85$, $SE = .07$; picnic: $M = 4.64$, $SE = .07$), $F(1, 58.35) = 4.92$, $p = .030$. However, no significant differences in AoA were observed between groups in each task, with controls and individuals with lvPPA producing words of similar AoA in each of the Cinderella storytelling ($p = .622$) and picnic picture description tasks ($p = .119$).

There was also a significant *group by part of speech* interaction, $F(2, 128.66) = 6.43$, $p = .002$. Within-group comparisons indicated that both groups produced verbs with significantly later AoA than nouns. For control participants, verbs had a higher AoA than nouns (verbs: $M = 4.80$, $SE = .06$; nouns: $M = 4.52$, $SE = .08$), $F(1, 105.48) = 5.96$, $p = .016$. This pattern was even more pronounced in the lvPPA group, where verbs were significantly later acquired than nouns (verbs: $M = 4.97$, $SE = .10$; nouns: $M = 4.53$, $SE = .06$), $F(1, 94.69) = 12.35$, $p < .001$.

Imageability

A linear mixed-effects model was conducted to examine differences in the imageability of words produced in discourse by individuals with lvPPA and healthy control participants, with total number of nouns and verbs generated included as a covariate.

A main effect of *group* emerged, $F(1, 89.76) = 4.25$, $p = .042$, indicating that individuals with lvPPA produced words with lower imageability ratings than control participants (lvPPA: $M = 5.27$, $SE = .06$; controls: $M = 5.41$, $SE = .03$). For example, individuals with lvPPA used less imageable words such as *thing, go, do*, while controls used more imageable words like *basket, castle, dance*.

Results also revealed a significant *group by task* interaction, $F(2, 53.30) = 37.58$, $p < .001$. Within-group comparisons showed that both groups produced more imageable words in the picnic scene than in the Cinderella task: controls (picnic: $M = 5.66$, $SE = .04$; Cinderella: $M = 5.16$, $SE = .05$), $F(1, 64.36) = 54.18$, $p < .001$; lvPPA (Picnic: $M = 5.53$, $SE = .09$; Cinderella: $M = 5.01$, SE

= .07), $F(1, 45.49) = 22.29$, $p < .001$. The interaction between group and task was not significant for either discourse task.

Additionally, there was a robust interaction of *group by part of speech,* $F(2, 52.23) = 359.21$, $p < .001$. Specifically, control participants produced verbs that were less imageable than nouns (verbs: $M = 4.68$, $SE = .05$; nouns: $M = 6.15$, $SE = .04$), $F(1, 61.70) = 492.36$, $p < .001$. A similar pattern was found in the lvPPA group, with verbs produced rated as significantly less imageable than nouns (verbs: $M = 4.43$, $SE = .10$; nouns: $M = 6.11$, $SE = .06$), $F(1, 45.33) = 233.21$, $p < .001$. Between-group comparisons revealed no significant differences for nouns, $p = .635$, but participants with lvPPA produced significantly less imageable verbs than controls (nouns: $M = 6.11$, $SE = .06$; verbs: $M = 4.43$, $SE = .10$), $F(1, 45.80) = 5.00$, $p = .030$.

A significant three-way interaction *(group by task by part of speech)*, $F(2, 52.27) = 8.44$, $p < .001$, revealed consistent noun–verb imageability differences across tasks and groups. For both lvPPA and control groups, nouns were more imageable than verbs in both the Cinderella and picnic tasks (all $p < .001$). Additionally, pairwise comparisons between the picnic and Cinderella tasks conducted separately for nouns and verbs, indicated that both groups produced more imageable nouns and verbs in the picnic scene compared to Cinderella. For controls, nouns produced for the picnic scene were more imageable than those produced for the Cinderella storytelling (picnic: $M = 6.28$, $SE = .04$; Cinderella: M = 6.02, $SE = .07$), $F(1, 26.24) = 12.46$, $p = .002$. This pattern held for nouns produced by participants with lvPPA (picnic: $M = 6.27$, SE = .06; Cinderella: $M = 5.96$, SE = .10), $F(1, 33.19) = 7.34$, $p = .011$. Similarly, controls produced verbs that were more imageable during picnic picture description than Cinderella storytelling (picnic: $M = 5.05$, $SE = .08$; Cinderella: $M = 4.31$, $SE = .08$), $F(1, 40.67) = 43.40$, $p < .001$. Individuals with lvPPA demonstrated a similar pattern, such that verbs produced during the picnic picture description were

more imageable than verbs produced during Cinderella storytelling (picnic: $M = 4.80$, $SE = .17$; Cinderella: $M = 4.07$, $SE = .08$), $F(1, 26.84) = 15.04$, $p < .001$. This difference is not particularly surprising, as the picnic picture provided participants with a concrete visual scene containing many easily imageable nouns and verbs, whereas the Cinderella story relied on recall and narrative generation, offering fewer concrete cues for high-imageability words. Further, a significant group difference emerged only for verbs in the Cinderella task, such that participants with lvPPA produced less imageable verbs compared to controls (lvPPA: $M = 4.07$, $SE = .08$; controls: $M = 4.31$, $SE = .08$), $F(1, 41.59) = 4.37$, $p = .043$.

Word Length

A linear mixed-effects model was conducted to examine group differences in word length across discourse tasks and parts of speech. The model included the total number of nouns and verbs produced and PND as covariates.

A significant interaction of *group by task* emerged, $F(2, 59.54) = 4.09$, $p = .002$. In the Cinderella storytelling task, controls produced words with greater number of phonemes than participants with lvPPA (controls: $M = 3.85$, $SE = .04$; lvPPA: $M = 3.62$, $SE = .06$), $F(1, 46.66) = 10.27$, $p = .002$. For instance, controls produced longer words such as *princess, slipper, carriage*, whereas participants with lvPPA more often used shorter forms such as *shoe, dress, man*. Similarly, in the picnic picture description task, controls used longer words than the lvPPA group (controls: $M = 3.72$, $SE = .03$; lvPPA: $M = 3.54$, $SE = .05$), $F(1, 58.36) = 10.20$, $p = .002$. Examples include controls producing *blanket, sandwich*, whereas participants with lvPPA favored shorter words like *food, eat*. Pairwise comparisons conducted separately for each group showed that for control participants, word length was significantly greater in the Cinderella task than in the picnic scene picture description task (Cinderella: $M = 3.85$, $SE = .04$; picnic: $M = 3.72$, $SE = .3$), $F(1,$

77.61) = 7.14, p = .009. However, for the lvPPA group, word length did not significantly differ between tasks, p = .260.

A significant interaction was also observed between *group and part of speech*, $F(2, 108.43) = 29.68$, $p < .001$. The tests of this interaction revealed that control participants produced significantly longer nouns compared to individuals with lvPPA (controls: $M = 4.02$, $SE = .04$; lvPPA: $M = 3.71$, $SE = .07$), $F(1, 54.34) = 15.87$, $p < .001$. For verbs, the difference was also significant, with controls producing longer verbs than participants with lvPPA (controls: $M = 3.55$, $SE = .04$; lvPPA: $M = 3.45$, $SE = .04$), $F(1, 78.29) = 4.36$, $p = .040$. Within-group comparisons showed that both groups produced nouns with greater number of phonemes compared to verbs. For controls, the mean difference between nouns and verbs was .47 phonemes (nouns: $M = 4.02$, $SE = .04$; verbs: $M = 3.55$, $SE = .04$), $F(1, 116.25) = 59.33$, $p < .001$. For individuals with lvPPA, the mean difference was .27 phonemes (nouns: $M = 3.71$, $SE = .07$; verbs: $M = 3.44$, $SE = .04$), $F(1, 79.88) = 8.44$, $p = .005$.

Phonological Neighborhood Density

To examine group differences in PND across discourse contexts and word classes, a linear mixed-effects model was conducted, with total number of nouns and verbs and word length included as covariates.

A significant *group by task* interaction emerged, $F(2, 68.39) = 3.68$, $p = .030$. The pairwise comparisons for this interaction revealed that for controls, PND was significantly higher in the picnic picture description task compared to the Cinderella storytelling task (picnic: $M = 23.82$, $SE = .34$; Cinderella: $M = 22.59$, $SE = .36$), $F(1, 61.20) = 7.16$, $p = .010$. This pattern was not observed for the lvPPA group, $p = .556$. Additionally, there were no significant differences between groups for either task.

There was a significant interaction of *group by part of speech,* $F(2, 128.30) = 21.95$, $p < .001$. Specifically, there were significant differences observed between lvPPA and controls for both nouns and verbs. For nouns, controls produced words with higher PND relative to individuals with lvPPA (controls: $M = 21.59$, $SE = .43$; lvPPA: $M = 20.06$, $SE = .63$), $F(1, 55.82) = 4.98$, $p = .030$. For example, controls used high-PND nouns such as *ball* and *cup*, whereas participants with lvPPA produced lower-PND nouns such as *food and house*. In contrast, for verbs, the pattern was reversed, such that controls produced verbs with significantly lower PND compared to individuals with lvPPA (controls: $M = 24.73$, $SE = .44$; lvPPA: $M = 26.51$, $SE = .74$), $F(1, 64.32) = 5.05$, $p = .028$. For example, individuals with lvPPA produced high-PND verbs such as *run* and *sit*, whereas controls produced lower-PND verbs such as *chase* and *gather*. Pairwise comparisons also revealed significant within-group differences in PND between nouns and verbs. Controls produced verbs with significantly higher PND than nouns (verbs: $M = 24.73$, $SE = .44$; nouns: $M = 21.59$, $SE = .43$), $F(1, 99.93) = 19.50$, $p < .001$, and the same pattern held for individuals with lvPPA (verbs: $M = 26.51$, $SE = .74$; nouns: $M = 20.06$, $SE = .63$), $F(1, 106.84) = 39.45$, $p < .001$.

Semantic Neighborhood Density

A linear mixed-effects model was used to examine differences in SND between individuals with lvPPA and control participants, across nouns and verbs produced in two discourse tasks (Cinderella and picnic scene). The model included covariates, including total number of nouns and verbs produced, word frequency, familiarity, and AoA, to control for potential lexical retrieval differences across individuals.

There was a significant main effect of *group* for SND, $F(1, 134.33) = 4.34$, $p = .039$. On average, words produced by individuals with lvPPA had higher SND than those produced by control participants (lvPPA: $M = .64$, $SE = .002$; controls: $M = .63$, $SE = .001$). For instance, participants with lvPPA produced words like *building*, *water, shoe,* with many close semantic

neighbors, whereas controls tended to produce more distinctive words such as *carriage, pumpkin, fairy*.

A significant interaction of *group by part of speech* was observed, $F(2, 126.24) = 18.44$, $p < .001$. Tests of this interaction indicated that individuals with lvPPA produced nouns with significantly greater SND than controls (lvPPA: $M = .65$, $SE = .003$; controls: $M = .63$, $SE = .003$), $F(1, 83.48) = 25.02$, $p < .001$. For verbs, no significant group difference was found, $p = .081$. When examined separately for each group, verbs produced by control participants had significantly higher SND than nouns (verbs: $M = .64$, $SE = .002$; nouns: $M = .63$, $SE = .003$), $F(1, 122.06) = 12.38$, $p < .001$. However, no significant difference between nouns and verbs was found for the lvPPA group, $p = .103$.

Arousal

A linear mixed-effects model was constructed to examine group differences in arousal ratings of nouns and verbs produced during discourse, accounting for the total number of nouns and verbs produced.

There was a significant *group by task* interaction, $F(2, 66.47) = 17.73$, $p < .001$. For the control group, arousal ratings were significantly higher for words produced in Cinderella storytelling compared to picnic picture description (Cinderella: $M = .44$, $SE = .005$; Picnic: $M = .42$, $SE = .005$), $F(1, 68.55) = 15.53$, $p < .001$. Similarly, for the lvPPA group, arousal ratings were higher in Cinderella storytelling than in picnic picture description (Cinderella: $M = .44$, $SE = .006$; Picnic: $M = .40$, $SE = .007$), $F(1, 63.37) = 20.93$, $p < .001$). For example, in the Cinderella task, both groups produced more emotionally arousing words such as *marry* and *fairy*, whereas in the picnic task they relied on less arousing terms such as *sit* and *basket*. This pattern is not unexpected given the inherently emotional and event-driven content of the Cinderella narrative, which includes themes of conflict, transformation, and romance, compared to the more neutral, everyday activities

depicted in the picnic scene. When comparing groups within each task, differences between lvPPA and controls did not reach significance in the Cinderella task ($p = .596$) but showed a trend toward significance in the picnic scene task, with controls producing overall higher-arousal words than participants with lvPPA (controls: $M = .42$, $SE = .005$; lvPPA: $M = .40$, $SE = .007$), $F(1, 66.15) = 3.78$, $p = .056$.

Additionally, there was a significant interaction of *group by part of speech*, $F(2, 64.59) = 137.07$, $p < .001$. For the control group, verbs had a higher arousal rating than nouns (verbs: $M = .48$, $SE = .005$; nouns: $M = .38$, $SE = .005$), $F(1, 65.96) = 222.93$, $p < .001$. This pattern was also observed in the lvPPA group, with verbs rated as more arousing than nouns (verbs: $M = .45$, $SE = .006$; nouns: $M = .39$, $SE = .006$), $F(1, 62.99) = 54.67$, $p < .001$. Between-group comparisons showed that individuals with lvPPA produced verbs that are significantly less arousing than control participants (lvPPA: $M = .45$, $SE = .006$; controls: $M = .48$, $SE = .005$), $F(1, 62.61) = 12.09$, $p < .001$. For example, the lvPPA group more often produced relatively low-arousal verbs such as *sit, walk, look, hold*, whereas controls produced more emotionally intense verbs such as *cry, chase, dance*. However, this pattern was not observed for nouns ($p = .321$).

Valence

To examine group differences in valence of nouns and verbs across discourse tasks, a mixed-effects model was conducted. Total number of nouns and verbs produced was included as covariates to control for individual variability in lexical retrieval.

A significant interaction of *group by part of speech* was observed, $F(2, 66.56) = 30.42$, $p < .001$. Pairwise comparisons revealed that in the control group, nouns were rated as significantly more positive than verbs (nouns: $M = .68$, $SE = .004$; verbs $M = .64$, $SE = .005$), $F(1, 62.05) = 45.76$, $p < .001$. Similarly, in the lvPPA group, nouns were also rated significantly more positively than verbs (nouns: $M = .69$, $SE = .006$; verbs $M = .65$, $SE = .008$), $F(1, 71.65) = 15.81$, $p < .001$.

Between-group comparisons for each part of speech did not reveal significant differences in valence ratings.

Contribution of Psycholinguistic Properties to Discourse Informativeness

Discourse informativeness was assessed using MCA with maximum possible scores of 54 for the picnic picture description and 102 for the Cinderella storytelling. For the picnic picture description, individuals with lvPPA produced a mean MCA score of 24.84 (*SD* = 8.45), corresponding to 46% of the maximum score, whereas control participants produced a higher mean score of 39.71 (*SD* = 7.36), or 74% of the maximum score. An independent samples *t*-test indicated that this difference was statistically significant, $t(34) = -5.59$, $p < .001$, reflecting a proportional difference of –0.28. For the Cinderella storytelling, participants with lvPPA had a mean MCA score of 30.30 (*SD* = 23.03), corresponding to 30% of the maximum score, while controls produced a mean score of 60.53 (*SD* = 17.44), or 59% of the maximum score. The group difference was again significant, $t(37) = -4.63$, $p < .001$, yielding a proportional difference of –0.29 (see **Table 4.7**).

Table 4.7. *Main Concept Analysis scores for individuals with logopenic primary progressive aphasia (lvPPA) and neurotypical controls (NC) across tasks*

Task	LvPPA *M* (*SD*)	NC *M* (*SD*)	LvPPA (% max)	NC (% max)	Percentage Difference	*t, p*
Picnic	24.84 (8.45)	39.71 (7.36)	46	74	-28	–5.59, < .001
Cinderella	30.30 (23.03)	60.53 (17.44)	30	59	-29	–4.63, < .001

To examine whether psycholinguistic properties predicted discourse informativeness, multiple linear regression analyses were conducted separately for each discourse elicitation task (picnic picture description and Cinderella storytelling). These analyses included only individuals with lvPPA and used MCA scores as the dependent variable.

Both models were statistically significant, explaining a substantial proportion of variance in informativeness (picnic: $F(9, 9) = 7.37$, $p = .003$, $R^2 = .881$; Cinderella: $F(9, 10) = 4.79$, $p = .011$, $R^2 = .812$). In both tasks, AoA emerged as the only significant predictor of informativeness (picnic: $\beta = .68$, $p = .042$; Cinderella: $\beta = .60$, $p = .045$), indicating that later-acquired words were associated with a higher MCA score. No other psycholinguistic variables significantly contributed to either model (see **Table 4.8**).

Table 4.8. *Results of regression analyses showing the effects of psycholinguistic properties on discourse informativeness (MCA) in the picnic picture description and Cinderella storytelling tasks in the logopenic primary progressive aphasia (lvPPA) group*

	Picnic scene picture description				**Cinderella storytelling**			
Psycholinguistic property	*B*	*SE*	β	*t, p*	*B*	*SE*	β	*t, p*
Frequency	4.64	5.88	.17	.79, .451	9.18	35.25	.11	.26, .800
Familiarity	-24.41	32.73	-.41	-.75, .475	-38.53	41.86	-.26	-.92, .379
AoA	**16.60**	**7.01**	**.68**	**2.37, .042**	**26.80**	**11.71**	**.60**	**2.29, .045**
Imageability	-2.02	5.60	-.08	-.36, .727	8.83	19.88	.11	.44, .666
Word length	-15.94	9.35	-.47	-1.71, .122	-27.43	25.02	-.44	-1.10, .299
PND	-.37	.37	-.20	-.99, .350	-2.35	1.86	-.38	-1.26, .236
SND	-100.42	182.48	-.21	-.55, .595	-560.01	327.43	-.37	-1.71, .118
Arousal	-.56	52.03	-.00	-.01, .992	-5.83	138.03	-.01	-.04, .967
Valence	-15.65	61.77	-.07	-.25, .806	-76.16	129.65	-.11	-.59, .570

Values in bold = significant predictor of MCA informativeness ($p < .05$). *B* and β represent the unstandardized and standardized regression weights of multiple linear regression, respectively. AoA = Age of acquisition, PND = Phonological neighborhood density, SND = Semantic neighborhood density, *SE* = Standard error.

Discussion

The present study examined psycholinguistic properties of nouns and verbs produced in discourse among individuals with lvPPA and neurotypical controls, as well as the contribution of these lexical properties to discourse informativeness. In this study, we aimed to analyze word properties across both a descriptive discourse task (picnic picture description) and a narrative discourse task (Cinderella storytelling) to provide insights into how these properties manifest in discourse contexts in lvPPA and how these features relate to communication effectiveness.

Psycholinguistic Properties of Nouns and Verbs in Descriptive and Narrative Discourse

The first aim of this study was to investigate whether psycholinguistic properties of words differed across groups, discourse tasks, and word classes (parts of speech). Results revealed systematic group-, task-, and class-related differences across multiple lexical dimensions. The observed patterns of effects consistently point toward compensatory lexical selection strategies in lvPPA that prioritize retrieval but sometimes at the expense of lexical specificity.

Our results demonstrated significant differences for the psycholinguistic property of *frequency*. The lvPPA group produced words with higher frequency than controls across both discourse tasks, and this effect was also significant for verbs (but not for nouns). These results align with the central role of frequency in lexical access such that high-frequency words have stronger resting activation and are generally easier to retrieve, an effect that is magnified in neurogenic and neurodegenerative naming impairment (Brysbaert & New, 2009; Kuperman et al., 2012). The disproportionate frequency effect for verbs in lvPPA is noteworthy because verbs often carry greater morphosyntactic and argument-structure demands and therefore pose larger retrieval costs (Collina et al., 2001). Under such pressure, speakers with phonological or retrieval impairments select higher-frequency verbs that are less susceptible to breakdown (Bastiaanse et al., 2016). Another noteworthy result was that controls produced words that were higher in frequency during the Cinderella storytelling relative to the picnic scene, whereas the lvPPA group did not show this task difference. This pattern in controls likely reflects normal discourse strategies that favor conventional, high-probability lexicalizations when recounting a familiar story. The same effect was not observed in lvPPA because retrieval constraints may produce a ceiling effect in retrieval strategy (i.e., persistent bias toward high frequency regardless of task).

For *familiarity*, the lvPPA group produced words with higher familiarity than controls in the picnic scene but not in the Cinderella narrative. This finding can be interpreted as evidence that subjective familiarity operates as an additional accessibility cue that individuals with lvPPA exploit when a stimulus context (i.e., picture) supports retrieval of salient and conventional labels (Howard & Gatehouse, 2006). Additionally, verbs (but not nouns) produced by individuals with lvPPA were rated as more familiar than verbs produced by control participants. This class-specific effect suggests that individuals with lvPPA preferentially access verbs that are high in experience (e.g., *run*, *drink*) rather than less familiar verbs (e.g., *chase*, *sip*). This pattern likely reflects the heavy reliance of individuals with lvPPA on familiarity-based retrieval routes to compensate for impaired phonological working memory and lexical access mechanisms (Dell et al., 1997; Hirsh & Funnell, 1995). By choosing highly familiar verbs, individuals with lvPPA reduce processing demands and increase the likelihood of successful retrieval, albeit at the cost of reduced lexical specificity. Further, participants with lvPPA produced more familiar words in the picnic task versus Cinderella (a within-group task effect), whereas controls did not show this task difference. This finding again shows that the picture context may amplify the familiarity effect in lvPPA because pictorial contexts cue prototypical object labels and associated high-familiarity action words, whereas storytelling requires selection of a broader set of thematic and sequence-driven verbs that may be less familiar (Bird & Franklin, 1996). For both groups, nouns were more familiar than verbs in the picnic description, whereas in the Cinderella narrative, this distinction diminished for lvPPA. This reduced differentiation may suggest a lexical leveling in narrative contexts, such that when the task imposes greater demands on event structure, verbal working memory, and semantic selection, such as during the Cinderella narrative, individuals with lvPPA may default to more familiar or easier-to-retrieve verbs, which can be accessed more rapidly due to lower retrieval

thresholds (Howard & Gatehouse, 2006). In turn, this would reduce familiarity contrast with nouns.

For *AoA*, across both groups, particpants tended to produce verbs that were later acquired compared to nouns, consistent with developmental evidence from the English language showing that nouns are typically learned earlier in life (Maratsos, 2014). Importantly, no significant between-group differences were observed in AoA, suggesting that lvPPA does not necessarily bias lexical retrieval toward earlier-acquired words in narrative contexts. Instead, both groups adjusted AoA depending on task: later-acquired words appeared more often in the Cinderella storytelling than in the picnic description. This pattern likely reflects fundamental differences in the lexical and conceptual demands of descriptive versus narrative discourse. Picture description tasks primarily elicit referents that are highly familiar and typically acquired early in life (e.g., objects, simple actions), whereas narrative storytelling requires speakers to retrieve abstract relational concepts, temporal events, and internal states, all of which are associated with later-acquired vocabulary (Bird & Franklin, 1996; Cummings, 2019; Juhasz, 2005; Ulatowska et al., 1990). The Cinderella story, in particular, includes themes such as transformation, social hierarchy, and romance, which tend to rely on lexicon acquired during later developmental stages. The finding that individuals with lvPPA showed similar AoA shifts suggests that despite their lexical retrieval difficulties, they retained access to relatively later-acquired words in narrative contexts. This finding contrasts with our reports that AoA exerts strong protective effects on lexical retrieval in lvPPA (Jebahi et al., 2024a, 2024b) but may indicate that discourse-level demands modulate AoA effects in lvPPA.

For *imageability,* the only significant effect at the group level was that participants with lvPPA produced less imageable verbs than controls in the Cinderella storytelling task. This pattern

can be explained by the consideration of three factors. First, imageability is a strong facilitator of lexical access because high-imageability items invoke richer perceptual and sensorimotor representations that support retrieval (Dymarska et al., 2023; Brysbaert et al., 2014). Verbs are less imageable than nouns and often encode relational or manner information that is not readily represented as a mental image (Vigliocco et al., 2011). Second, narrative production (unlike picture description) places demand on thematic, relational, and sometimes abstract action terms. Therefore, successful storytelling requires selection of verbs that carry specific event information (Ulatowska et al., 1990; Ferretti et al., 2001). Qualitative inspection of the discourse samples in the present study suggested that individuals with lvPPA frequently relied on highly generic, semantically light verbs (e.g., *go, do, make*), which are typically low in imageability. This tendency was especially apparent in contexts requiring precise event specification. Although this observation aligns with prior accounts of verb retrieval under constrained processing resources (Dell et al., 1997), the current analyses did not formally quantify the proportion or distribution of generic versus semantically specific verbs. Future work should explicitly test this hypothesis by examining verb specificity and imageability in relation to narrative demands and disease severity.

Word length, defined as the number of phonemes in words, also differentiated the groups. Individuals with lvPPA produced shorter words than controls across tasks and word classes. Production of shorter words, with fewer phonemes, in lvPPA likely reflects phonological effects such that longer words typically require more phonological assembly and are more susceptible to phonological buffer and retrieval failures, particularly in disorders with phonological-processing deficits (Dell et al., 1997; Gorno-Tempini et al., 2011; Kuperman et al., 2012). Additionally, control participants produced longer words in the Cinderella task than in the picnic description whereas lvPPA did not show this task difference. In neurologically unimpaired adults, production

of words with greater number of phonemes in the Cinderella storytelling task relative to the picnic description likely reflects increased narrative demands. Storytelling requires retrieval of temporally sequenced events and causal relations across extended discourse, favoring the use of more specific, morphologically and phonologically longer lexical items (e.g., *transform, escape, recognize*). In contrast, the visually constrained picnic description task supports reliance on shorter, highly accessible labels sufficient for local scene description. The absence of a task-based word length modulation in lvPPA suggests a restricted productive lexicon that constrains the ability to shift to longer, potentially more specific lexical items in narrative contexts. The word length effects may reflect phonological vulnerability in lvPPA that can constrain adaptive lexical choices in discourse, while in unimpaired adults, word length modulations across tasks reflect typical adjustments to communicative demands (Nickels, 2014; Herbert et al., 2008).

Phonological neighborhood effects further revealed different lexical selection patterns across groups and tasks. Controls produced words with higher PND in the picnic task than in Cinderella, which was not observed in lvPPA. This task-based difference in controls likely reflects automatic activation of many phonologically similar object labels when a visual referent is present, a facilitative context for normally functioning lexical systems (Vitevitch & Luce, 1999; Vitevitch, 2002). Individuals with lvPPA consistently produced higher-PND words across both tasks which suggests reduced flexibility in task-dependent retrieval of phonologically related lexical items. This likely reflects reliance on phonological-neighborhood scaffolding, where dense neighborhoods provide partial phonological cues that support retrieval of words under weakened assembly mechanisms (Goldrick & Rapp, 2007; Middleton & Schwartz, 2010). In addition, PND effects differed for nouns and verbs. Controls produced nouns with higher PND than the lvPPA group, whereas individuals with lvPPA produced verbs with higher PND than controls. PND has

a nuanced role such that dense phonological neighborhoods can either facilitate access through activation spreading among similar forms or impede selection through increased competition, depending on task demands and the integrity of phonological processing (Vitevitch & Luce, 1999). The reversed pattern for nouns and verbs (i.e., higher verb PND and lower noun PND in lvPPA) may indicate differential strategies across word classes. For verbs, participants with lvPPA may rely on phonologically dense forms that provide scaffolding through partial activation of neighbors, thereby supporting retrieval under conditions of weakened phonological assembly (Goldrick & Rapp, 2007; Middleton & Schwartz, 2010). For nouns, participants with lvPPA may avoid high-PND targets because dense neighborhoods increase lexical competition when phonological monitoring and selection are impaired (Harley & Bown, 1998; Gordon, 2002; Mirman et al., 2011). It is also possible that, overall, verbs tend to have less dense phonological neighborhoods than nouns (Gahl et al., 2012). Consequently, even "dense" neighborhoods for verbs may provide more effective facilitation, whereas high-PND nouns may reach a threshold where competition outweighs facilitation. This threshold-dependent effect may explain why verbs benefit from phonological scaffolding in lvPPA, while nouns are more susceptible to interference from competing neighbors (Mirman & Magnuson, 2008). These mixed effects align with aphasia literature showing that PND exerts both facilitative and inhibitory influences depending on context (Mirman & Magnuson, 2008; Dell et al., 1997).

We observed differences related to *semantic neighborhood* effects as well. The lvPPA group produced nouns with higher SND than controls (e.g., *building*, *water*), but no group difference was found for verbs. This pattern suggests that participants with lvPPA preferentially relied on prototypical nouns that are embedded in dense semantic spaces due to overlapping perceptual and functional features (McRae et al., 2005; Reilly & Desai, 2017). By using words

that are in feature-rich neighborhoods, individuals with lvPPA may capitalize on redundancy in semantic representations to support retrieval despite phonological and lexical access deficits (Cree et al., 1999; Rogers & McClelland, 2004). This compensatory reliance is less applicable to verbs because their semantics are grounded in relational and event-based structures that are less directly captured by feature-based neighborhood measures (Vigliocco et al., 2011).

Additionally, controls produced verbs with higher SND than nouns, a pattern not observed in individuals with lvPPA. This aligns with the expected pattern of higher verb than noun SND, consistent with the central role of action vocabulary in structuring narratives through dense relational links across events (Ferretti et al., 2001; Pulvermüller, 2005). The absence of this noun–verb dissociation in lvPPA converges with evidence of verb vulnerability across psycholinguistic properties in this group. Instead of drawing on verbs embedded in dense relational networks, lvPPA speakers tended to rely on semantically underspecified light verbs (e.g., *go, do, get*) that provide broad semantic coverage but are not closely tied to dense neighborhoods (Hoffman et al., 2013; Mack et al., 2021).

Affective properties also played a role. Controls produced verbs that were rated as more *arousing* than those produced by individuals with lvPPA, with no group difference for nouns. Arousal influences lexical processing in neurotypical adults such that higher arousal can increase attention but may slow retrieval (Citron, 2012; Kousta et al., 2011). In the present data, the tendency of individuals with lvPPA to produce verbs that are less arousing suggests a lexical restriction toward more emotionally neutral action words, expressed by light verbs with minimal semantic weight (e.g., *go, make*) rather than highly arousing and semantically specific verbs (e.g., *attack, embrace*). Taken together, these findings suggest that high-arousal verbs, while semantically rich, impose additional processing costs because they are often complex, context-

dependent, and demanding of semantic integration (Chwilla, 2022). For individuals with lvPPA, in whom phonological vulnerability and emerging semantic weakness already strain retrieval (Gorno-Tempini et al., 2011), these costs may outweigh potential communicative value. As a result, lexical selection in lvPPA appears to favor lower arousal, more accessible, light verbs, which supports output fluency but reduces semantic specificity and emotional nuance in discourse.

These findings converge on a coherent profile of lexical selection in lvPPA: individuals show systematic biases toward words that are easier to access (i.e., higher in frequency and familiarity, shorter in length, embedded in supportive phonological and semantic neighborhoods, and lower in imageability and arousal) particularly when producing verbs. These adaptations reflect compensatory strategies that preserve communicative output under conditions of phonological and lexical retrieval vulnerability, but they may come at the cost of reduced lexical specificity, such as relying on generic verbs (e.g., *go*, *do*, *make*) rather than semantically rich verbs (e.g., *chase*, *embrace*) and using nouns that are prototypical (e.g., *house*, *water*) instead of more distinctive or context-specific items (e.g., *castle*, *lake*). Control speakers flexibly modulate their lexical choices (e.g., selecting longer, more imageable, semantically dense, and arousing words in narrative storytelling), while speakers with lvPPA appear constrained to a narrower lexical repertoire characterized by generality and reduced detail. Importantly, this imbalance shows the susceptibility of verbs to psycholinguistic constraints in lvPPA. The particular susceptibility of verbs in lvPPA may arise from their greater phonological and morphosyntactic demands as verbs often carry tense and agreement inflections, and they must encode argument structures that map onto multiple roles in a sentence. Although relatively few studies have investigated these factors specifically in lvPPA, evidence from broader PPA research suggests that online processing of verb argument structure and morphosyntax is impaired across variants, including the logopenic variant

(e.g., impaired verb-argument and morphosyntactic processing in PPA; Barbieri et al., 2021).These factors increase the phonological planning and working memory demands required for accurate production, making verbs more vulnerable than nouns under conditions of impaired phonological assembly and retrieval as observed in lvPPA.

Contribution of Psycholinguistic Properties to Discourse Informativeness

The second aim of this study was to examine whether psycholinguistic properties predicted discourse informativeness in lvPPA, as measured by MCA. Across both tasks, AoA emerged as the only significant predictor, with later-acquired words associated with greater informativeness. This finding is theoretically important, as it suggests that reliance solely on early-acquired words may not support successful communication of story gist in lvPPA. Rather, producing later-acquired words, which are often more specific and informative, appears to enhance discourse quality.

In the context of lvPPA, it appears that what most enhances discourse informativeness is not ease of retrieval per se, but lexical specificity. Later-acquired words tend to encode finer-grained meanings and narrower category membership, thereby carrying more informational value in discourse (Brysbaert & Ellis, 2016; Juhasz, 2005). In contrast, properties that generally ease access in discourse for individuals with lvPPA (e.g., frequency, familiarity, word length, PND, SND, and arousal as found in our LME analysis results) did not independently predict MCA once considered together, likely because they bias speakers toward generic and high-probability forms that improve their lexical access but add limited novel content (Hoffman et al., 2013; Richardson & Dalton, 2016). This pattern aligns with the arbitrary mapping hypothesis account of AoA in which early learned items establish robust mappings, whereas later-learned items are acquired through incremental differentiation that places them within more elaborate and discriminative

semantic and phonological networks, which makes them more informative when retrieved (Ellis & Lambon Ralph, 2000).

The absence of between-group AoA differences in our LME (both groups produced (1) later-acquired words more often in Cinderella than in the picnic task, and (2) later-acquired verbs compared to nouns) is theoretically meaningful. lvPPA is characterized by lexical access impairments driven primarily by phonological and working memory deficits, with better preserved core semantic knowledge (Gorno-Tempini et al., 2011). As a result, when narrative contexts place demands on more specialized vocabulary, individuals with lvPPA are still able to access later-acquired words rather than being restricted to earlier-learned items. Importantly, within the lvPPA group, variability in retrieving these later-acquired words directly influenced discourse informativeness such that successful production of such words was associated with higher MCA scores, as MCA favors accurate and specific main concepts over just fluency (Nicholas & Brookshire, 1993; Richardson & Dalton, 2016). This pattern aligns with our prior evidence that the effect of AoA on word retrieval in lvPPA is partly mediated by phonological ability (Jebahi et al., 2024b). Later-acquired words typically place greater demands on phonological assembly (Barry et al., 2001; Brown & Watson, 1987; Kittredge et al., 2008), meaning that individuals with relatively preserved phonological skills are better able to retrieve them. However, AoA also retained a direct effect beyond phonological mediation, showing its role as a multifactorial construct that captures both phonological and semantic dimensions of lexical organization.

Taken together, these findings help integrate discrepancies with single-word studies (where earlier AoA often shows resilience; Jebahi et al., 2024a, 2024b) by highlighting a task-dependent trade-off: earlier-acquired words maximize accessibility in single-word tasks, whereas later-acquired words maximize informativeness in discourse. Clinically, this suggests that therapy

should not only strengthen access to early, high-availability vocabulary but also explicitly target later-acquired words, particularly verbs linked to narrative main concepts, while providing phonological supports to offset retrieval demands. Approaches such as semantic feature analysis to enhance specificity (Boyle & Coelho, 1995), Verb Network Strengthening Treatment to support lexical retrieval and generalization across contexts (Edmonds et al., 2009), with potential to be further optimized through a structural cueing hierarchy (Jebahi & Kielar, 2025), and narrative or script-based interventions to align lexical targets with discourse goals (e.g., Cherney et al., 2008) may be especially well suited to leverage these insights.

CHAPTER 5: GENERAL DISCUSSION

Overview

The three studies presented in this dissertation sought to characterize how psycholinguistic properties influence lexical retrieval in logopenic variant primary progressive aphasia (lvPPA) across three production contexts that differ in cognitive and linguistic demands: confrontation naming (Chapter 2: Study 1), generative verbal fluency (Chapter 3: Study 2), and descriptive and narrative discourse (Chapter 4: Study 3). A consistent and unifying result across studies was the centrality of age of acquisition (AoA): AoA was the strongest predictor of confrontation naming accuracy (Study 1), it was the only property with significant differences between controls and individuals with lvPPA and it predicted the total number of correct words produced in animal fluency and showed an association with phonological skill within the lvPPA group (Study 2), and it was the only psycholinguistic property to predict discourse informativeness in this population (Study 3). Importantly, the patterns of psycholinguistic results varied across tasks. Specifically, Study 1 and Study 2 revealed robust AoA effects at the single-word naming and fluency levels, whereas Study 3 revealed a broader set of accessibility-driven adaptations (higher frequency and familiarity, lower imageability, shorter words, selective use of phonological and semantic neighborhood structure, and lower arousal) and showed class- and task-specific effects that were not evident in the single-word studies. In this chapter, I integrate and interpret these results collectively, consider their theoretical and clinical implications, acknowledge limitations, and propose future directions.

Integration and Interpretation of Results

Taken together, the three studies provide converging and task-sensitive evidence about how psycholinguistic properties shape lexical retrieval in lvPPA. The emerging patterns suggest that lexical breakdown in lvPPA reflects reorganizations of lexical selection under constraint.

Below, I unpack these findings by first examining the central role of AoA, then accounting for the divergence of accessibility-driven patterns across tasks and finally offering a mechanistic synthesis that integrates these results into a unified explanatory framework.

Centrality of Age of Acquisition Across Tasks

AoA was the most consistent predictor across studies: it explained variance in confrontation naming accuracy (Study 1), it related to the number of items produced in animal fluency and was partly mediated by phonological skill (Study 2), and it uniquely predicted discourse informativeness (Study 3). This pattern can be understood if AoA is treated as a multifactorial marker that indexes two complementary cognitive loci. On one hand, earlier-acquired words tend to have more robust phonological and lexical form representations, which facilitates retrieval when phonological assembly is impaired (Barry et al., 2001; Brown & Watson, 1987; Alario et al., 2004). This robustness explains why AoA predicted confrontation and generative naming, tasks that place increased demands on rapid word form retrieval and selection (Dell et al., 1997; Levelt et al., 1999). On the other hand, later-acquired words often encode more differentiated semantic content and therefore convey greater conceptual specificity (Brysbaert & Ellis, 2016). Thus, when later-aquired lexical items are retrieved, they contribute to the informational content of discourse (Juhasz, 2005; Brysbaert & Ellis, 2016; Steyvers & Tenenbaum, 2005). This semantic specificity explains why AoA predicted Main Concept Analysis (MCA) scores in discourse.

The regression results of Study 2 further support the view that AoA reflects both phonological and semantic dimensions. Both phonological and semantic abilities significantly predicted the number of words generated during animal fluency in lvPPA. Specifically, stronger phonological and semantic skills were linked to the production of later-acquired words, suggesting

that successful access to these words requires support from both processing domains. This reliance is consistent with accounts that early acquired words possess holistic phonological representations that reduce phonological processing demands (Brown & Watson, 1987; Belke et al., 2005), while later-acquired words rely on more effortful phonological assembly and deeper semantic integration (Brysbaert & Ellis, 2016). Consequently, AoA's consistent effect across tasks in lvPPA likely reflects its unique place for both phonological and semantic systems: words acquired earlier benefit from form-based resilience, whereas words acquired later draw on semantic richness to enhance communicative informativeness (Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006).

Divergence of Accessibility-Driven Patterns

Although AoA was central to single-word naming ability in Study 1 and Study 2, the discourse findings of Study 3 revealed a more complex psycholinguistic profile, which points to task-related divergence in lexical selection strategies.

Confrontation and generative naming tasks place relatively increased demands on the lexical system. In confrontation naming, the task is to map a visual stimulus onto its lexical form. Impairments therefore most directly expose vulnerabilities in conceptual representation, semantic–phonological mapping, and/or phonological form retrieval (Dell et al., 1997). Because lvPPA is characterized by phonological impairment and early-acquired words have stronger phonological form-level representations, AoA emerged as the dominant predictor in this context for individuals with lvPPA (Gorno-Tempini et al., 2011; Jebahi et al., 2024a). Generative naming is less stimulus-driven but it is still constrained by executive demands (e.g., clustering and switching) and requires repeated lexical access within a category. Under these conditions, retrieval efficiency becomes critical. Words with robust phonological representations are accessed more quickly and with fewer breakdowns. Accordingly, individuals with lvPPA rely heavily on early-acquired words, which

offer phonological resilience and thereby maximize output within time limits (Brown & Watson, 1987). By contrast, discourse production engages a wider set of cognitive and linguistic processes, including conceptual organization, episodic memory, syntactic planning, and pragmatic monitoring (Ulatowska et al., 1990; Nicholas & Brookshire, 1995). This complexity opens multiple routes to lexical selection and allows both strengths and weaknesses in the system to surface. Accordingly, the lvPPA group's discourse (in comparison to that of controls) showed reliance on words that were more frequent, familiar, shorter, and lower in imageability and arousal, with differential exploitation of neighborhood structure, but not different in their AoA.

The divergence may also reflect differences in opportunity structure. Confrontation naming uses a limited pre-specified stimulus set (Kaplan et al., 1983). Similarly, generative naming is bounded by category membership (Troyer et al., 1997; Henry & Crawford, 2004). These single-word level tasks constrain the lexical space from which responses can be drawn. In contrast, discourse provides greater variability and flexibility in word choice which may enable compensatory strategies to manifest (Ulatowska et al., 1990; Marini et al., 2011). This explains why discourse may improve sensitivity to individual psycholinguistic biases. Specifically, the open-ended nature of discourse exposed how lvPPA speakers adaptively re-weight lexical selection pressures in real-time communication (Zimmerer et al., 2020; Wright & Capilouto, 2009). Therefore, the broader pattern observed during discourse is not inconsistent with the AoA findings. Rather, it reveals additional context-dependent selection rules that operate when production is less constrained.

Additionally, the strategic goals of each task differ. In confrontation and generative naming, success is measured by retrieval accuracy, favoring early acquired words with robust phonological representations that maximize access under lvPPA-related phonological

vulnerability (Barry et al., 2001; Dell et al., 1997). By contrast, discourse is evaluated by conveying meaning, coherence, and narration (Ulatowska et al., 1990; Marini et al., 2011). Under these demands, additional properties influence selection. High-frequency and familiar words reduce retrieval thresholds, shorter words ease phonological buffering, and lower imageability or arousal reflect reliance on more accessible vocabulary (Brysbaert & New, 2009; Paivio, 1991). Selective use of neighborhood structure further shows adaptive strategies to support retrieval while avoiding interference (Mirman & Magnuson, 2008).

Integrating these findings, a unified model of lexical breakdown in lvPPA emerges. AoA functions as a marker of both phonological robustness and semantic specificity. Phonological integrity acts as determinant, especially in lvPPA where phonological vulnerability is characteristic of the disorder (Gorno-Tempini et al., 2011). When phonological ability is relatively preserved, it permits retrieval of later-acquired, more semantically informative items, which support communicative informativeness. When phonological ability is compromised, retrieval defaults to earlier-acquired, more resilient words. Task demands and external supports further modulate these outcomes. Picture cues (i.e., confrontation naming) amplify AoA effects in naming, time limits and efficient retrieval similarly highlight AoA effects in fluency (i.e., generative naming), and discourse engages broader cognitive-linguistic systems which expose compensatory reliance on frequency, familiarity, word length, imageability, arousal, and neighborhood structure (Ulatowska et al., 1990; Nicholas & Brookshire, 1995; Mirman & Magnuson, 2008). This model accounts for AoA dominance in naming and fluency and the broader accessibility-driven psycholinguistic adaptations that emerge in discourse.

Theoretical Implications

The three studies refine understanding of the nature and locus of lexical retrieval impairment in lvPPA and clarify how psycholinguistic properties shape production depending on task demands. At the broadest level, the results support a view of lvPPA as a disorder in which phonological and phonological working-memory vulnerabilities are primary but where semantic abilities exert important and interacting influences on which words are available in production. This account brings together findings across this dissertation's single-word and discourse contexts and has implications for models of lexical access and representation. Two sets of theoretical considerations follow from these findings. First, the results shed light on the role of psycholinguistic properties in shaping lexical access in lvPPA, with AoA emerging as a central property across tasks. Second, the findings can be situated within interactive and connectionist models of lexical access (Dell et al., 1997), which predict the task- and deficit-dependent patterns observed across studies.

Psycholinguistic Properties, Cognitive Locus, and Lexical Access

The convergent evidence for AoA across tasks shows that AoA is a central psycholinguistic property of the lexicon in lvPPA. The AoA results are consistent with theoretical positions that consider AoA a property that reflects both phonological-level robustness and semantic differentiation (Ellis & Lambon Ralph, 2000; Jebahi et al., 2024b). Early acquired words tend to develop stronger and more holistic phonological representations that facilitate retrieval under stress (Brown & Watson, 1987). This explains why AoA predicted performance in tasks that depend on rapid word form access (e.g., confrontation and generative naming; Jebahi et al., 2024a; 2024b). At the same time, later-acquired words often have more differentiated semantic structure and therefore add greater conceptual specificity when produced. This semantic dimension explains

why AoA predicts informativeness in discourse (Brysbaert & Ellis, 2016). Importantly, the results from Study 2 (Jebahi et al., 2024b) show that the production of later acquired words is predicted by better phonological and semantic abilities and that phonological ability partially provides access to later-acquired items. Thus, AoA relies on semantic and phonological representations and importantly these processing abilities modulate AoA effects depending on integrity of phonological and semantic skills.

Additionally, the studies clarify how task context determine which psycholinguistic properties become determinant in lvPPA. Confrontation and generative naming favor phonological-level robustness because these tasks either require single-shot retrieval from a pictured referent or rapid, repeated retrieval under time pressure. Both conditions highlight AoA and phonological resilience. In contrast, discourse is communicatively driven and provide many lexical alternatives. It therefore facilitates accessibility-driven adaptations (e.g., higher frequency and familiarity, higher or lower neighborhood denisties, lower imageability and arousal) that preserve conversational flow at the expense of specificity (Nicholas & Brookshire, 1995; Ulatowska et al., 1990; Brysbaert & New, 2009). This pattern supports integrative frameworks of lexical access (e.g., Dell's interactive activation models and connectionist accounts) in which both resting activation (e.g., modulated by frequency, familiarity) and network structure (e.g., modulated by AoA, neighborhood density) interact with processing constraints to determine selection outcomes (Dell et al., 1997; Ellis & Lambon Ralph, 2000; Rogers & McClelland, 2004).

Interactive and Connectionist Models of Lexical Access

The present findings also align with interactive activation and connectionist framework that model reciprocal influences among phonological and semantic units (Dell et al., 1997). This

account emphasizes that retrieval outcomes are not determined by a strict sequence of stages but by graded activation dynamics within distributed networks.

In single-word tasks (Jebahi et al., 2024a; 2024b), individuals with lvPPA showed advantage for earlier-acquired words, consistent with the idea that words with stronger and more entrenched representations are more easily accessed when minimal contextual scaffolding is available. In discourse (Study 3), however, individuals adapted retrieval strategies based on their frequency, familiarity, word length, and neighborhood density, reflecting the model's prediction that lexical selection dynamically re-weights available inputs under differing demands (i.e., tasks). Speciffically, these results show the interactive weighting process central to connectionist models: lexical retrieval in lvPPA reflects a shifting balance between entrenched representational robustness (psycholinguistic effects) and system-level resource allocation (phonological vs. semantic support). This adaptive interplay explains why psycholinguistic effects diverge across single-word versus discourse contexts and strengthens the case for models that view lexical processing as guided by distributed representations and cross-level feedback.

Clinical Implications

The findings of the studies of this dissertation suggest clinical implications for assessment and treatment in lvPPA, and for supporting everyday communication. First, assessment practices should move beyond single-word tests and include tests that measure discourse-level functioning and the psycholinguistic makeup of spontaneous output. Standardized confrontation naming and fluency tasks remain essential to characterize core deficits and to estimate phonological capacity (Gorno-Tempini et al., 2011), but clinicians should also collect and analyze connected speech samples and score informativeness with structured metrics such MCA. MCA has strong ecological validity and aligns with listener judgments of communicative success, making it a suitable

outcome metric when the therapeutic goal is improved real-world communication (Nicholas & Brookshire, 1995; Richardson & Dalton, 2016). In addition, routine assessment of phonological skills (e.g., phonological manipulation) and semantic integrity (e.g., synonym judgment, single-word comprehension) will help identify whether these abilities are likely to support retrieval of later-acquired and content-rich words (Jebahi et al., 2024b; Leyton et al., 2015).

Further, the results of the studies imply a principled approach to target lexical selection in therapy. As mentioned earlier, AoA emerged as a central variable: later-acquired words carry informational value for discourse but place greater phonological assembly demands. Thus, when the clinical aim is to improve discourse informativeness, selection of later-acquired semantically specific words (particularly verbs tied to main concepts of narratives) is warranted, provided that phonological supports are layered to offset access demands. Conversely, when the immediate objective is to increase lexical accessibility or overall word output, targeting early-acquired words may yield the greatest clinical benefit. Given that AoA was the most consistent predictor of lexical outcomes across studies, and may subsume related psycholinguistic dimensions such as frequency and familiarity, focusing on early AoA items offers clinicians the most efficient means of supporting word retrieval, particularly in later stages of the disease or when phonological processing resources are limited. Such an approach may facilitate gains in communicative efficiency and confidence by capitalizing on more robust lexical representations (Brysbaert & New, 2009).).

The profile revealed by the three studies would support integrative semantic and phonological intervention approaches rather than single-domain training. Treatments that strengthen semantic networks around target verbs and nouns (for example, Semantic Feature Analysis) and those that explicitly train verb–argument structure (Verb Network Strengthening

Treatment, VNeST) are well suited to increase the specificity and generalization of lexical retrieval to sentence and discourse contexts (Boyle & Coelho, 1995; Edmonds et al., 2009). Additionally, because phonological integrity partially mediates access to later-acquired items, incorporating phonologically focused therapies (e.g., structured phonological manipulation training, combined with cueing hierarchies) can increase the probability that later-AoA high-information words will be retrievable in connected speech (Kendall & Nadeau, 2016; Beeson et al., 2010). In practice, this supports a combined approach where clinicians initiate semantic strengthening around clinically relevant targets (especially verbs central to a person's stories and daily activities), add phonological training and cueing, then embed targets in increasingly naturalistic discourse and script practice to promote functional use (Edmonds, 2016; Cherney et al., 2008). This approach aligns with contemporary principles of aphasia rehabilitation and is appropriate to the profile of lvPPA identified in the present dissertation (Boyle & Coelho, 1995; Edmonds et al., 2009; Kendall & Nadeau, 2016).

Limitations

Several limitations in the studies of this dissertation should be acknowledged. First, the sample sizes in each study were modest, mostly due to the relative rarity of lvPPA. PPA itself is a low-incidence clinical syndrome, affecting roughly 3 out of 100,000 individuals (Gorno-Tempini et al., 2011), which inherently constrains recruitment. At the same time, this rarity underscores the unique scientific opportunity: unlike stroke-induced aphasia, which arises from sudden vascular injury, PPA allows us to study the language system as it undergoes focal and progressive neurodegeneration. Second, although the studies examined multiple tasks, the cross-sectional design prevents strong claims about how lexical retrieval patterns evolve over disease progression. Third, there was partial overlap in participants with lvPPA across the three studies included in this

dissertation. While this may limit the extent to which findings can be assumed to reflect entirely independent samples, the use of overlapping participants also represents a methodological strength. Specifically, because the same individuals completed multiple discourse tasks, this within-subject design reduced between-subject variability and enabled more direct and controlled comparisons of how task demands influence lexical retrieval. As a result, the observed patterns are less likely to be driven by individual differences and instead more closely reflect systematic effects of task and linguistic variables. Nonetheless, future studies with fully independent samples would further strengthen the generalizability of these findings. Finally, discourse analyses, although ecologically valid, remain susceptible to task-specific influences (e.g., story familiarity, narrative style) and cognitive demands (e.g., planning and memory retrieval) that may affect lexical selection.

Future Directions

Building on the findings of the three studies of this dissertation, several avenues of research would advance both theoretical understanding and clinical relevance. Future work should clarify the mechanisms by which AoA exerts its dual phonological and semantic effects, examine how task demands modulate the influence of other psycholinguistic properties, and test models of lexical access in lvPPA using neuroimaging approaches. From a clinical standpoint, future studies should test whether tailoring treatment to psycholinguistic properties (e.g., targeting late-acquired and semantically rich words, or training strategies that compensate for phonological vulnerability) improves informativeness and functional communication. Incorporating discourse-level measures into intervention trials is especially promising, as these metrics capture communicative informativeness beyond single-word accuracy and better reflect real-world outcomes.

Conclusions

Across confrontation naming, fluency, and discourse, psycholinguistic properties highlight how lvPPA affects lexical selection. AoA stands out as an organizing variable because it reflects both the phonological retrievability of forms and their semantic informativeness. AoA links word-level production likelihood (what is easiest to produce) to discourse-level communicative value (what is most useful to say). In discourse, individuals with lvPPA adopt compensatory strategies such that they favor accessible, short, familiar, and neighborhood-supported words, but these strategies trade accessibility for specificity and narrative richness. Clinical assessment and treatment that understand this trade-off, combine phonological strengthening with targeted training of later-acquired and discourse-relevant vocabulary, and measure functional outcomes at the discourse level may preserve meaningful communication in lvPPA.

APPENDIX A – INFORMED CONSENT FOR INDIVIDUALS WITH LOGOPENIC VARIANT PRIMARY PROGRESSIVE APHASIA

The University of Arizona Consent to Participate in Research

Study Title: Enhancing language function with Transcranial Direct Current Stimulation (tDCS)

Principal Investigator: Aneta Kielar, Ph.D.

Sponsor: Arizona Alzheimer's Consortium, Arizona Department of Health Services, and National Institute on Aging

This is a consent form for participation in a research project. Your participation in this research study is voluntary. It contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. *Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to participate.* If you decide to take part in the study, you will be asked to sign this consent form. If you decide you don't want to participate, there will be no penalty to you, and you will not lose any benefit you normally have.

Why is this study being done?
This study's goal is to use non-invasive brain stimulation (NBS) techniques to treat language impairments in Primary Progressive Aphasia (PPA). The purpose of this study is to combine behavioral language intervention with individualized noninvasive brain stimulation techniques, called transcranial direct current stimulation (tDCS) to help the brain reorganize around damage and improve language functions. The successful combination of speech-language therapy with noninvasive brain neuromodulation can speed up recovery and enhance patients' quality of life. TDCS is a method of stimulating the brain that does not require any sedation or surgery. TDCS is a technique that sends a weak electrical current through the scalp to stimulate the brain areas below. The information gained from this research study will aid in the development of therapies to improve language in people with neurological conditions that affect language use.

New research shows that in some people there are naturally occurring gene variants that may make them more responsive to treatment. These genes code for a family of proteins called Brain Derived Neurotrophic factors (BDNF) and other neurotrophic proteins that promote neuroplasticity. These neurotrophic proteins can be detected in the blood. Recent research findings indicate that treatment may increase production of these neurotropic proteins and in turn this may improve response to the language therapy. This is why it is important for our research to collect genetic information and blood samples. This will allow us to identify naturally occurring genes involved in neuroplasticity. You can participate in the language treatment and tDCS without donating cheek swabs and blood samples.

What will happen if I take part in this study?

- If you agree to participate in this study, we will perform a screening evaluation to make sure youare eligible to participate in the study. Once complete, you will be asked to participate in behavioral language tasks, MRI scans and non-invasive brain stimulation sessions.

- The number and sequence of visits are described below, but they may not necessarily occur inthis order, depending on scheduling. Each visit will take approximately 1-2 hours to complete
- If you agree, we will perform cheek swabs for genetic testing. This will allow us to identify naturally occurring genes involved in neuroplasticity. We would also like to collect blood samples from the vein in your arm to test for the presence of neurotropic proteins.
    - A Federal law, called the Genetic Information Nondiscrimination Act (GINA), generally makes it illegal for health insurance companies, group health plans, and most employers to discriminate against you based on your genetic information. Be aware that this Federal law does not protect you against genetic discrimination by companies that sell life insurance, disability insurance, or long-term care insurance.

Summary of study sequence and procedures that you may complete:
Weeks 1-2: Baseline screening, language testing, one magnetic resonance imaging (MRI) scan, one electrophysiology recording (EEG-ERP), cheek swabs, and baseline blood sample collection.
Weeks 3-5: Five tDCS-MRI sessions to determine most effective treatment
Week 6: rest period

Weeks 7-9: tDCS with Language Treatment Part 1
Week 10-11: Post-treatment assessment, collection of blood sample

2 months rest-period,

Week 12: Language assessment, Collection of blood sample before Treatment Part 2
Weeks 13 to 14: tDCS with Language Treatment Part 2
Weeks 15-16: Post-treatment assessment, collection of blood sample

2 months rest-period,

Week 17: 2-month follow-up, language assessment, one MRI scan, one EEG-ERP session
Week 18: Collection of blood sample at follow-up (approximately 2 months after Phase 2 treatment is completed).

Study Procedures:
Initial Screening and Study Overview: If you agree to participate in this study, we will ask some questions to make sure you are eligible to participate in the study. The initial screening may involve questions about MRI and tDCS safety, demographic information (e.g., your age, education, language use) and health history. We will also perform a brief hearing test that involves listening to sounds.

Week1
Baseline Phase: During the initial baseline visit, you will complete a language assessment (2 hours), one MRI scan (1 hour), and 1.5-2hour EEG-ERP evaluation. Testing can be distributed over several days during that first week, if you prefer. The language testing and EEG will take place at the Department of Speech, Language and Hearing Sciences. MRI scanning will take place at the University of Arizona, Translational Bioimaging Resource (TBIR) in the basement of Bioscience Research Laboratory (BSRL) building.

During this baseline testing, you will complete tasks that measure your language and memory abilities. The tests will be conducted in person with the experimenter in an assessment room. During the tests, you may listen to words or sentences or look at pictures, and respond by pointing to pictures or speaking. You may also be asked to complete questionnaires in writing.

During the MRI scan, you will lie down on the MRI bed and rest while the MRI machine takes pictures of your brain. This MRI scan is non-invasive and no chemical will be used in our collection of MRI data. The MRI scan will last approximately 1hour. It takes this long because the MRI will be gathering different sets of images (structural, functional, and diffusion) that will help us examine patterns in your brain. The structural MRI provides information on the shape and size of the brain. The functional MRI measures brain activity while you perform language tasks. The diffusion-tensor MRI can measure how brain regions are connected. There will be a "resting-state" MRI scan, meaning that you do not need to do anything in the scanner; you will simply be asked to try to remain awake and as still as possible. You will be able to talk to the research staff via an intercom system while you are in the scanner and the research team will work to make you as comfortable as possible for the duration of the scan. Once this scan is complete, the MRI images will be analyzed by the study team to map out your brain. This "map" will then help us to figure out the specific location of the brain areas for the tDCS session. We need an MRI for each person because every person's brain is organized in a slightly different way. You can stop the MRI exam at any time and withdraw yourself from the study without penalty.

During EEG assessment you will sit in the chair while your brain responses are recorded using electrodes attached to the elastic net. While wearing the net with electrodes attached to it, you may be reading or listening to words or sentences and pressing a button.

Cheek (Buccal) swab**:** During your baseline visit we will collect sample of cells from inside of your cheek by swabbing with a sterile oral swab. This will be done by a trained research technician wearing gloves and face mask. Buccal sample will be collected only once at the baseline. The buccal cells are flat and thin cells that line your cheeks and lips. To ensure that your samples are not contaminated with any other cells, we ask that you avoid brushing your teeth, eating, drinking or smoking for 30 minutes before swabbing your inner cheeks. To collect the sample the inside of each cheek will brushed in a rolling motion with a sterile swab for 30 seconds (1 minute total per swab). Two swabs will be collected. The sample will be labelled with your participant number and dated. The entire process will take less than five minutes. The research technician will take your swabs to the specialized laboratory at Arizona Molecular Clinical Core where samples will be securely stored and prepared for analysis. Prior to transfer to Clinical Core these samples will be stored in a locked container in the Language and Neuroimaging Laboratory at the Speech Language and Science Building.

Blood Sample Collection: The blood draw will occur in a private location. We will collect 2 tubes with up to 10 ml of blood (about 2 teaspoons) at five time points, specified on page 2 under "Summary of study sequence and procedures that you may complete".

- You will be asked to fast overnight (a minimum of 6 hours) before the blood draw. Fasting means no food or drinks such as coffee, tea, milk, or juice (water is OK).

During the test you will be seated in a reclining chair, and the blood sample will be collected by venipuncture which is the collection of blood from a vein. The total duration of the procedure will be about 10-15 minutes. The research assistant will take your sample to a specialized laboratory at Arizona Molecular Clinical Core where samples will be stored in a secure location for analysis.

_____ I give permission for collection of my cheek swab sample

_____ I give permission for collection of my blood sample

Weeks 2 to 5: Optimal tDCS protocol and montage finding sessions

During the other five visits, you will receive a single dose of tDCS, and perform a short language task before and after tDCS. In these sessions, we will use images from the MRI scan acquired during the baseline session as a map to precisely place where the tDCS electrodes will be positioned on the head. The purpose of these sessions is to learn which type tDCS stimulation is most effective for you.

We will apply stimulation to the left hemisphere brain areas affected by the PPA or to the brain areas in the right hemisphere. The purpose of this part of the study is to find tDCS approach that will be most effective in improving your language function. The total duration of each of these visits is approximately 1 hour.

We will also complete sessions in which you will receive sham ("fake") tDCS. The sham tDCS is designed to mimic active tDCS; it looks and feels identical, but it is not capable of stimulating the brain. You will not know whether the research team is using the fake TDCS or the real TDCS until after you have finished all sessions of the study.

The purpose of this approach is to learn which protocol creates the greatest improvement in function in the brain areas that process language. *We want to identifya protocol that will be most effective for you.*

Weeks 7-8 and weeks 11-15: Language Treatment + tDCS

After Phase 1 is complete, there will be four (4) treatment weeks, during which you will be asked to visit University of Arizona Tucson Campus every day (5 days each week) to receive personalized language therapy paired with a single tDCS session. During two treatment weeks, you may receive active tDCS combined with language therapy. During the other two treatment weeks, you may receive sham ("fake") TDCS. You will receive both active and fake TDCS throughout the study, but you will not know in which order you received the different types of stimulation until after you have completed the study. The tDCS will take 20 minutes to complete and the language therapy sessions will take approximately one hour to complete. We will need 15-20 minutes for setup. Thus, the total duration of individualized therapy session is approximately 1.5 hours. There will be one therapy session per day.

During the baseline week you will undergo a single one-hour MRI scan and language testing. During rest period between treatment weeks you will undergo language testing (2 hours) and one-hour MRI or EEG exam (1.5-2 hours). During this testing, you will complete tasks that measure your language and memory abilities. This is to see how your language is improving after the treatment. Blood sample will be collected after the treatment Phase ends.

2 months follow-up week

After the treatment weeks are completed, we ask you to visit the laboratory for the 2 month-follow-up to test long-term effects of the tDCS treatment. During this session, we will ask you to complete final language assessment (2 hours), single MRI scan (1 hour) and one EEG scan (1.5-2h). Testing can be distributed over several days if you prefer. The last blood sample will be collected at this follow-up.

Description of Stimulation Technique:

What is tDCS?

TDCS is a procedure that sends weak electrical currents between points on the scalp. Some of this current flows through the brain, and may induce temporary changes in brain activity lasting 30-60 minutes beyond the time of stimulation. TDCS is believed to be very low risk. Possible adverse effects are discussed below in the Potential Risks and Discomforts section below. TDCS has been applied in more than 4900 studies and hundreds of people to treat various neurological and psychiatric conditions, including depression, epilepsy, chronic pain and Parkinson's. In this study we will use tDCS to enhance language function

What can I expect during tDCS protocol?

During the tDCS procedure, you will be seated in a chair. We will place electrodes over certain parts of the head, depending on what brain area is being targeted. The electrodes are made of rubber and are enclosed in soft sponge pads. When the machine is turned on, electrical current will flow from the positive electrodes(s) to the negative electrode(s). You may feel a slight itching or tingling on the scalp when the current is applied. We will place an active electrode over a certain part of the head, depending on what brain area that is being targeted.
During this experiment, we will administer up to 2 milli-amperes of current, for up to 20 minutes. These parameters are consistent with the current clinical and research practice.

Description of Imaging Techniques:

Magnetic Resonance Imaging (MRI). During several visits before and after tDCS intervention we will perform an MRI scan of your brain. One MRI brain scan will be performed at the baseline assessment. There will be one MRI scan after the treatment is complete and at the 2-month follow up. Each MRI session takes 1 hour to complete.

The MRI scan provides a three-dimensional picture of the structure of the brain. The MRI technique uses magnets and radio waves to construct a picture of the brain on a computer. MRI does not involve radiation (i.e., ionizing radiation) used for an x-ray or computerized tomography (CT) scan. For the MRI procedure, you will be asked to lie on a padded bed that willbe moved into a tunnel-like machine for the MRI scan of your brain. It is important that you remain as still as possible during the scan. Movement will not be dangerous to you in any way, but can blur the picture of your brain. The MRI machine is equipped with an intercom system that will allow you to communicate with the MRI technician at any time. When pictures of your brain are acquired the MRI machine makes loud knocking noises, but this is normal. If you feel uncomfortable during the scan and wish to discontinue the procedure, you will be taken out of the machine at your request.

You will be given instructions outside of the MRI scanner about the scanning so that you are comfortable and know what to expect. You will lie quietly in the scanner, while structural images of your brain are acquired. You may be asked to read or listen to words or sentences, while pictures of your brain are being acquired. If response is required, you will respond by

pressing a button. MRI is a noninvasive procedure and measures blood flow to your brain as you perform the task. For some scans you will not need to perform any experimental task and will be allowed to rest throughout the MRI scan. The MRI scan takes approximately one hour (1 hour). The MRI procedure used in this project includes research-oriented scans not typically used in clinical MRI assessments.

In order to make sure the MRI procedure is safe, you will be asked to fill out a screening form before participating in this study. This research MRI scanner operates within FDA guidelines and is considered a *non-significant* risk device. *The minimal risks are described in the Risk Section below.*

What is the purpose of multiple MRI scans in the follow-up visits?
We need a baseline MRI to figure out the placement of tDCS electrodes on the head. The MRI is sensitive to functional changes in activity in the brain and it will be used as a tool to accurately measure the short-term and long-term effects of tDCS intervention. After a single session of tDCS these changes in brain activity are only temporary so the MRI sessions will need to immediately follow the tDCS session. The MRI images collected after tDCS will be compared to those acquired immediately before the tDCS session to measure changes.

Electroencephalography (EEG). During initial baseline and follow-up visits to the Department of Speech, Language and Hearing Sciences, you will undergo an electroencephalography exam. EEG session will take 1.5 to 2 hours to complete. When brain cells become active, they produce tiny electrical signals that can be measured by special sensors placed on the head. For this procedure, the participant will be seated in a chair, while the net with small sensors embedded in it will be placed on the participant's head. The sensors look like white round pieces of plastic. In order to obtain clear recordings, the electrodes are soaked in a clear saline solution before they are placed on the head. If you become uncomfortable or no longer wish to participate at any time during the experiment, the procedure will be terminated at once.

While wearing the sensor net on your head you will read or listen to the sentences, words or simply rest. The language stimuli will be presented on the screen in front of you or you will hear them through a speaker/earbuds, and will make a decision about them. You will indicate your decision by pressing a button or answering questions. Your eye movements also may be monitored while you perform some of these tasks. Your participation in this part of the study will last 1-2 hours. The EEG recording will be compared to those acquired before the tDCS sessions to identify any changes.

Will video or audio recordings be made of me during the study?
The researchers will make an audio recording during the study so that scoring of responses can be evaluated at a later time by our research team. No names or identifying information (i.e. your address or contact information) will be used on any of the recordings. In some cases, video recordings may be also taken. **You will be informed before any recording occurs.** The transcriptions will be done by the researchers, including PI, investigators, research assistant, or the qualified and trained lab personnel.

_____ I give permission for audio recording to be made of me during my participation in this research study

_____ I do not give permission for audio recording to be made of me during my

participation in this research study

_____ I give permission for video recording to be made of me during my participation in this research study

_____ I do not give permission for video recording to be made of me during my participation in this research study

How long will I be in the study?
The participation in the study may require several visits to the University of Arizona and the Department of Speech, Language, and Hearing Sciences. The visits will be spread out over several weeks. Each tDCS + language treatment session will take 1.5-2 hours. The language treatment will be administered over a 4 weeks period, five days per week. There will be a two weeks break between the treatment weeks. The longest time the whole study may take is 15 weeks. There will be a follow-up session 2 months after the treatment to check how your language is improving.

How many people will take part in this study?
Approximately 240 participants will be enrolled in this study. We plan to recruit 120 controls and 120 individuals with language disorders.

Can I stop being in the study?
Your participation in this study is voluntary. You may refuse to participate in this study. If you decide to take part in the study, you may leave the study at any time. No matter whatdecision you make, there will be no penalty to you and you will not lose any of your

usual benefits. Your decision will not affect your future relationship with the University of Arizona. If you are a student or employee at the University of Arizona, your decision will not affect your grades or employment status. No new data will be collected from thatpoint. Upon participant's request any data that has not been processed to remove identifying information will be destroyed. However, we are not able to remove any data that have already been analyzed, processed to remove identifying information, or linked and aggregated with other data.

What risks or benefits can I expect from being in the study?
It's unlikely that there will be any harm or discomfort associated with this study. However, if you experience any discomfort or fatigue at any time during the experiment, please inform the researchers and the experiment can be stopped to allow for a break. On occasion, a participant may experience anxiety about the procedure or about his/her performance in the experiment. To alleviate these feelings, you will be de-briefed about the study immediately following the experiment.

Behavioral Testing: The tasks during the assessment phase of the study have no more risk than you would come across in everyday life. Although researchers try to avoid any risks, some of the tasks may be difficult for you and you could find the testing frustrating or upsetting. In some cases, you may find testing to be boring. Every effort will be made by the evaluators to make the process as comfortable as possible.

General mood will be assessed using a geriatric depression scale. This assessment takes about 3-5 minutes. For participants showing indication of significant depression we will suggest that they

visit their family doctor. We will provide a list of resources offered by the Arizona Center on Aging: http://aging.arizona.edu/program/elder-care-resource-interprofessional-providers, Geriatric Mental Health Foundation: http://www.gmhfonline.org/, and Seniors Resource Guide: http://www.seniorsresourceguide.com/directories/Tucson/search.php?region=AZ01&topic=409. You are welcome to ask any questions that you may have.

Transcranial Direct Current Stimulation (tDCS): The most commonly reported adverse effects is skin irritation (redness, itching, tingling, burning, etc). To minimize these risks, tDCS studies shall exclude subjects with existing skin problems at or near the stimulation site. TDCS is believed to be very low risk. This study will only use tDCS parameters that are within current safety guidelines, which have been established after careful review of hundreds of participants/patients receiving tDCS. In the unlikely event of an emergency, one of our researchers will contact emergency services, while another researcher will stay with you at all times prior to the arrival of help.

There is also a risk of potential loss of confidentiality. Every effort will be made to keep your information confidential; however, this cannot be guaranteed. Information on how the research team maintains confidentiality is found under, "Will my study-related information be kept confidential?" in this document.
If you experience any adverse events (a bad effect) after leaving the tDCS laboratory, please contact members of the study team listed below. Importantly, however, the research team and the University of Arizona may not be held responsible for medical care or the financial burden of any research related injury should one occur. Despite these potential risks, the health and safety of participants is the number one priority in this study.

EEG-ERP recording: There are no known health risks associated with the ERP recording procedures. Participants may experience some mild discomfort from sitting still during EEG or from the pressure of the electrode net. However, efforts will be made to position participants comfortably and to allow rest periods when needed. In rare cases the skin that is extremely dry may be prone to irritation from the saline solution used in this procedure. If a headache or skin irritation develops, the ERP recording procedure will be discontinued. In very rare cases there may be some mild skin irritation from the electrodes, if the net is tight fitting. However, the pink spots disappear a few minutes after the electrode net is removed. For participants who undergo EEG, every attempt will be made to make the process as comfortable as possible.

MRI: This research MRI scanner operates within FDA guidelines and is considered a *non-significant* risk device. This means the risks are minimal so long as appropriate precautions are taken. You will be screened before the scan. Significant risks may exist for people with:

- Cardiac pacemakers
- Metal clips (stents) on blood vessels
- Artificial heart valves
- Artificial arms, hands, legs, etc.
- Brain stimulator devices
- Implanted drug pumps
- Ear implants & augmentation (e.g. cochlear implants, hearing aids)
- Eye implants, metal fragments in eyes, colored contact lenses
- Exposure to shrapnel or metal filings (e.g. military combat, sheet metal workers, welders)
- Other metallic surgical hardware anywhere in your body or on your skin

- Certain tattoos with metallic ink (please tell us if you have a tattoo)
- Certain transdermal (skin) patches such as NicoDerm (for tobacco dependence), Transderm Scop (for motion sickness), or Ortho Evra (birth control)

Please let the technologist know if you have any of these items or anything else metallic or magnetic that will not be removed before the MRI scan.
Significant risks can also arise if metallic or magnetic objects and materials are brought into the scanning area with you (e.g. jewelry, piercings, pocket knife). Such items could get pulled into the magnet at great speed and can cause serious injury. You will not be allowed to bring anything with you into the scanning room. You will be provided a secure locker for your belongings.
The Siemens MRI scanner that will be used for your scan is approved by the FDA for routine clinical and research studies. This is also true for most of the peripheral components used with the scanner as well as most of the scan types that are performed on the scanner. However, as part of your session we may use non-FDA-approved components, scans, and/or software. In all cases these components, scans, and software comply with all FDA guidelines with respect to MRI safety.

The noises that you hear inside the scanner are normal. You will be given ear protection to help muffle the noise. The noise may be annoying, but it is not harmful. The scanner may be uncomfortable if you have trouble laying on your back for long periods of time and you may find the experience unsettling if you are bothered by small spaces. An intercom will allow you to communicate with the technician.

Cheek (Buccal) swab: The collection of cell samples from the inner cheek is non-invasive and painless. However, swabbing the inner cheek could potentially result in slight grazing if carried out too roughly. To avoid this, we will help you with the collection on the day. In a case that you are unable to provide cheek swab at the time of appointment, you can collect the sample yourself. In such case, we will provide detailed instructions to safely collect and return your samples. To prevent contamination, we use sterile swab kits and technician collecting samples is trained to follow inflection prevention protocols. The technical will wear gloves and face mask while collecting the samples.

Blood Sample Collection: You may experience some temporary discomfort when the blood sample is taken. You may feel some pain when blood is drawn. There is a small risk of fainting, bleeding, bruising, or possible infection at the blood draw site. In order to minimize these risks, we will swab the site of the blood draw with alcohol to disinfect the area, use disposable sterile needles and tubes to collect blood, and apply pressure to the site following the blood draw to minimize bruising. To protect against infection, we will also provide instructions on how to care for the injection site and watch it for signs of infection. It is important to know that these blood tests performed in the study are strictly for research purposes. The researcher using your blood sample is not a physician and therefore not qualified to make clinical recommendations. Furthermore, no physicians will review the results of these blood tests as the researchers are not using this test to make a diagnosis.

We will not collect blood samples from participants with known contraindications. It is important that you inform researchers if you have contraindications for giving blood. The contraindications may include infection or hematoma at a prospective venipuncture site, injured

or massively swollen arm, thrombotic or inflamed vein, excessive rash, sacring, abscess or burns at the collection site.

Please inform research staff if:

- you think that you may have a medical condition that might prevent you from giving blood sample
- your medical condition changed
- you are taking new medications that may affect your ability to give blood sample

What benefits can I expect? While participating in this study, you will receive direct and personalized language therapy. There are no assurances of benefit from participating in this study. However, we anticipate that participants enrolled in the treatment protocol will benefit from language treatment. Research to date suggests that most of the participants will improve their language skills as a result of participation in the treatment. This study combines language therapy with tDCS in an effort to optimize the benefits observed with language therapy alone. It is unclear that combining language therapy with non-invasive brain stimulation will enhance the benefits of language therapy, but we expect that it will. The overall benefit of this study lies in the potential to discern the therapeutic value of the *tDCS* therapy. We anticipate that the knowledge gained in this study will contribute to the future care and treatment of patients who have language disorders. There is no medical benefit for participation in the MRI scan. You may request a copy of your scan.

There are no direct benefits to you for providing the cheek swab and blood sample. The samples will be used only for laboratory research and not for helping to diagnose, treat or manage a particular medical condition. Your participation may allow the researchers involved in this study to learn more about genetic factors and blood biomarkers that could potentially predict response to the intervention in diseases such as PPA and Alzheimer's.

Will I be paid for taking part in this study?
You will receive $10 per hour for the baseline language assessment and $10 per hour for the follow-up language assessment. You will be compensated $20 for baseline EEG and $20 for 2-month follow-up EEG assessment. You will receive $20 for baseline MRI scan and $20 for 2 month follow-up MRI scan. We will also compensate you $20 for the cheek swabs and $20 for each blood sample collection. The financial compensation will not be provided for the treatment partof the study. In total you will receive $240 for completing the study. We will provide parking, or compensate participants for transportation expenses to the University of Arizona campus, using city bus or taxi fare. In the event of an early withdrawal from the study, reimbursementwill be prorated to match the number of sessions that you participated in. Any payment for participation in a research study is considered taxable income for you. If your payment for this research study or a combination of research studies is $600 or more for all or any dollar amount for undocumented noncitizens in a calendar year (January to December), you will receive the appropriate IRS Form for tax reporting purposes from the university. Please note, if you are an employee of UArizona, any compensation from a research study is considered taxable income. For any compensation or reimbursement, you receive, we are required to obtain identifiable information such as your name, address, and, for amounts >$50, Social Security number for financial compliance purposes. This information will be recorded using a dedicated form and will be kept in a separate and secure location than the study data itself. No data with subject identifiers will be released. Your

information will be secured in a locked file cabinetin a locked office or laboratory while they are active in the data collection of the study phase, andafter the study is completed it will be moved to a secure storage.

What are the costs of taking part in this study?
Aside from your time, there are no costs for taking part in this study. The nature of the intervention study requires several visits to the University of Arizona campus. The estimated time required to complete each component the study includes: cognitive testing that may take up to 2 hours, EEG = 1.5-2 hours, MRI scan = 1 hour each (Total = 3 hours). The tDCS treatment sessions will take about 1.5 to 2 hours each day (15 minutes setup, 20 min TDCS stimulation and 30-60 min speech language therapy). The scan times listed above are approximate and subject to adjustment and preferences. You will not be charged for the cheek swab or blood sample.

Will my study-related information be kept confidential?
To protect confidentiality all participants will be assigned a subject code and this number will be recorded on all test protocols and MRI header files. All behavioral and imaging data will be entered into an electronic database using subject codes rather than names. Your information will be stored in a locked file cabinet, in a locked office. The computer files will be protected with a password and this consent form will be filed in a secure area. Only qualified study personnel have access to the files.

We will protect your privacy by labeling your cheek swabs and blood samples and related information only with a code and keeping the key to the code in a password protected file. Only the research team will have access to the file. When the study is completed and the data has been analyzed, the list will be destroyed. The genetic information obtained in this study will not be linked to your medical record.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include Principal Investigator and research study personnel directly involved in the study. Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. Representatives of regulatory agencies such as Office of Human Research Protection (OHRP), and entities such as the University of Arizona Human Subject Protection, or the University of Arizona Institutional Review Board may access your records to make sure the study is being run correctly and that theinformation is collected properly. The institution where these study procedures are being performed (University of Arizona) may also see your information. However, any information that is shared with them will be coded with a number so that they cannot see who you are.

Representatives from these entities can see information that has your name on it if they come to the study site to view the study records. If there are any reports about this study, your name will not be in them.

This research is covered by a Certificate of Confidentiality from the National Institutes of Health. This means that the researchers cannot release or use information, documents, or samples that may identify you in any action or suit unless you say it is okay. They also cannot provide them as evidence unless you have agreed. This protection includes federal, state, or local civil, criminal, administrative, legislative, or other proceedings. An example would be a court subpoena.

There are some important things that you need to know. The Certificate DOES NOT stop reporting that federal, state or local laws require. Some examples are laws that require reporting of child or elder abuse, some communicable diseases, and threats to harm yourself or others. The Certificate CANNOT BE USED to stop a sponsoring United States federal or state government agency from checking records or evaluating programs. The Certificate DOES NOT stop disclosures required by the federal Food and Drug Administration (FDA). The Certificate also DOES NOT prevent your information from being used for other research if allowed by federal regulations.

Researchers may release information about you when you say it is okay. For example, you may give them permission to release information to insurers, medical providers or any other persons not connected with the research. The Certificate of Confidentiality does not stop you from willingly releasing information about your involvement in this research. It also does not prevent you from having access to your own information.

What happens if I am injured because I took part in this study?
Side effects (injury) can happen in any research study. These effects may not be your fault or the fault of the researcher involved. There are no known side effects associated with this study; however, side effects that are not currently known may happen and require care. You don't give up any of your legal rights by signing this form. If you suffer an injury from participating in this study, you should seek treatment. The University of Arizona has no funds set aside for the payment of treatment expenses for this study. You will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study. If you believe that you are injured because of the research or are billed for medical care for injuries that you feel has been caused by the research, you should contact the Principal Investigator Aneta Kielar, Ph.D., at 520-621-5105.

Will I hear back on any results that directly impact me? Your MRI scans are not intended to provide medical benefit to you, and the technologist and/or investigators running your scan are not trained or licensed to clinically review your images. If we send you home with a copy of your scan you are free to do as you wish with the images, but we make no promises as to the clinical value of the data. If a technologist and/or investigator notices something they think is unexpected in your images, the investigator may provide de-identified images to a licensed radiologist for further review. In the extremely rare case that this radiologist finds an irregularity, the technologist or investigator will contact you and recommend that you consult your primary care physician. You will be provided copies of your images, but otherwise, this will be on your own time and at your own cost. The University of Arizona and its employees have no funds set aside for the payment of treatment expenses that may arise from you volunteering for an MRI scan.

There may be instances in which an abnormality exists but is not noticed by the technologists or investigators. In addition, there may be instances where you have one or more pre-existing conditions that make it impossible to determine if a scan shows something unexpected. We are not trained to clinically review images, and our data and/or analyses are not intended to treat, diagnose, or replace the expertise of a medical doctor or a medical diagnosis. As such, the University of Arizona and its employees are not responsible for abnormalities that go undetected through participation in these volunteer activities. Please do not rely on our data and/or analyses

to reveal abnormalities.

The cheek swabs and blood samples are used for research purposes and will not have direct benefits to you. The importance of this information to your health is unknown. Because all samples will be analyzed as a batch and not individually, we will not be able to provide feedback on individual results.

Will my study-related information be used for future research?
Anonymized data will be stored at the end of the study for future analysis by the PI and Co-Investigators, but no identifying or personal information will be included. The information from this study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential, and no personal information will be made public. Neither your identity nor any personal information will be available to anyone other than the investigators. No personal information will be disclosed in any resulting publication or presentation. Only aggregate data will be reported in the publications or presentations.

The data that will be preserved and may be shared, include basic demographic information, numeric responses and numeric language and cognitive test scores in excel or the text format, as appropriate. At the conclusion of the study numerical data without personal identifiers may be shared with scientific community through University of Arizona ReDATA repository. The neuroimaging data may be shared through OpenNeuro repository.

All shared data will be coded, and original data will be maintained at the University of Arizona. We may share aggregated behavioral assessment scores for each treatment phase in an excel spreadsheet on ReData depository linked to the relevant study.

The cheek swabs and blood samples that we collect during the study will be stored at University of Arizona Health Science Biorepository for potential use in future analyses or studies. These samples might be very useful in helping to address future research questions that may arise following the completion of this study. At the time of storage, the specimen will be identified only by study numbers and any link to your personal information will be protected. The Principal Investigator for this study will oversee the storage of these specimens and will regulate access to these samples by other researchers. Because your personal information will no longer be linked to the stored specimen, it will not be possible for a participant to have future access to the biological samples. The numerical genomic data will be shared according to the NIH policy and state and institutional Human Subject Protection regulations. The identifying information will be removed before sharing.

During this study, samples (cheek swabs and blood) will be collected from you for research as described in this consent form. Your samples may be sent to the laboratories at the National Centralized Repository for Alzheimer's Disease (NCRAD) for further analysis. These laboratories are national resources supported by the National Institute on Aging (NIA) that prepare and store biological specimens from all over the world. Because identifying information is removed from all samples, no results will be returned to research participants.

Your data and biospecimens may be shared with other interested researchers. However, the decision to share your data and biospecimens is controlled by the Principal Investigator of this study. To get your data and biospecimens, future researchers must seek approval from the

Principal Investigator of this study. The researchers must agree not to try to identify you.

Principal Investigator will have a code key that can be used to link to your identifying information. The code key will be securely stored. Your name and identifying information will be removed from any data and biospecimens you provide before they are shared with other researchers. Researchers cannot easily link your identifying information to the data and biospecimens.

We will do our best to protect your data and biospecimens during storage and when they are shared. However, there remains a possibility that someone could identify you. There is also the possibility that unauthorized people might access your data and biospecimens. In either case, we cannot reduce the risk to zero.

You will not receive any direct benefit from sharing your data and biospecimens. However, sharing your data and biospecimens may contribute to research that could help others in the future.

If there is future collaboration, data transfer between institutions or collaborators will be done in a secure manner, without your personal or identifying information. Consent forms will be kept in a separate location than the study data itself. No data with subject identifiers will be released.

We would like to know if you would be interested in participating in other studies with us in the future. You don't have to participate. It is your choice. Even if you agree now you can still change your mind later. **Do you agree for other researchers at the Department of Speech and Hearing Sciences, University of Arizona to contact you about other research studies?**

_____I give permission for other researchers to contact me

_____I do not give permission for other researchers to contact me

Data sharing. Some journals and grant agencies require that coded raw data be made available in some manner to researchers who may benefit from sharing of the data. Coded data from this study may be shared with the research community at large to advance science and health. We will remove or code any personal information that could identify you before files are shared with other researchers to ensure that, by current scientific standards and known methods, no one will be able to identify you from the information we share. The samples and data will be sent with only study code number attached. Your name or other directly identifiable information will not be given to repositories.

Who can answer my questions about the study?
For questions, concerns, or complaints about the study you may contact **Principal Investigator Dr. Aneta Kielar at 520-621-5105.**

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Human Subjects Protection Program Director at 520-626-8630 or online at https://research.arizona.edu/compliance/human-subjects-protection-program.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact the Principal Investigator.

An Institutional Review Board responsible for human subjects research at the University of Arizona reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

A description of this clinical trial will be available on http://www.ClinicalTrials.gov, as required by U.S. Law. This Web site will not include information that can identify you. At most, the Web site will include a summary of the results. You can search this Web site at any time.

Signing the consent form

I have read (or someone has read to me) this form, and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject	Signature of subject	Date
Printed name of person authorized to consent for subject (when applicable)	Signature of person authorized to consent for subject (when applicable)	Date
Relationship to the subject		

Investigator/Research Staff

I have explained the research to the participant or the participant's representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or to the participant's representative.

Printed name of person obtaining consent	Signature of person obtaining consent	Date

APPENDIX B – INFORMED CONSENT FOR CONTROL PARTICIPANTS

ARIZONA

The University of Arizona Consent to Participate in Research

Study Title: Modulation of Neural Networks for Language In Healthy Aging and Acquired Language Disorders

Principal Investigator: Aneta Kielar, Ph.D.

Summary of the research:
This is a consent form for participation in a research study. Your participation in this research study is voluntary. This consent contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate.

You are being asked to take part in a research study being conducted by the University of Arizona. The information in this form is provided to help you decide whether to participate or not. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you don't want to participate, there will be no penalty to you, and you will not lose any benefit you normally have.

Purpose: Why is this study being done?
The purpose of this research is to understand how brain supports language processing in healthy adults, and how language is affected by neurological disease, stroke, brain injury or aging. This study involves research. The information gained from this research study will help us to understand how language is represented in the healthy brain, affected by neurological disease, and will aid in the development of therapies to improve language in people with neurological conditions.

What will happen if I take part in this study?
This study may involve several activities. The activities involve pencil and paper language testing, electrophysiological recording of your brain activity, and MRI scan of your brain. You are being asked to participate in one or more of the research activities listed below. Initial your decision on the next page. In order to make sure the MRI procedure is safe, you will be asked to fill out a screening form prior to participating in this study.

Research Procedures:
Cognitive and language assessment
Behavioral experiment on the computer
functional MRI
Structural MRI
EEG exam

Time commitment: The EEG session may take about 2 hours. MRI session takes about 1 hour. The cognitive testing may take two sessions of 2 hours each. The study task can be completed on different days and can be spread out over several weeks. We can schedule a time that is convenient for you.

Risks/Benefits. You may experience some fatigue or frustration from the study tasks. Some task may be boring to you. Researcher will ensure that you are comfortable during the study and have sufficient breaks to minimize fatigue. There are no direct personal or medical benefits from participation in this study.

_____ I give my permission for the assessment research that involves: speaking, listening, reading, writing tasks, in a clinical testing room

_____I give my permission for Familiar Handedness Questionnaire that asks some questions about hand preferences for myself and my family members

_____ I give my permission for the behavioral experiments requiring listening or reading words or sentences

_____ I give my permission for the electroencephalography (EEG) research that involves: reading or listening to words or sentences, looking at pictures, and making a response by pressing buttons and recording of resting brain activity

_____ I give my permission for the MRI brain scan that involves: An MRI brain scan while I rest in the scanner

_____ I give my permission for the CT brain scan that involves: A CT scan while I rest in the scanner

_____ I give my permission for the fMRI brain scan that involves: A brain scan while I read or listen to words or sentences and make a response, while lying in an MRI scanner

Detailed Description of Study Procedures:
Initial Screening: If you grant consent to participate in this study, we will perform a screening evaluation to make sure you are eligible to participate in the study. The initial screening may involve questions about demographic data (e.g., your age, education, language use), health history, and brief hearing screening that involves listening to sounds. Once complete, you will be asked to participate in behavioral and neuroimaging testing at the University of Arizona. The behavioral testing and EEG procedure will take place at the Department of Speech, Language and Hearing Sciences. Structural and functional MRI scanning will be conducted at the

University of Arizona (Tucson Campus) using Siemens Skyra 3T with Syngo MR. The scanner is located in the BioScience Research Laboratories (BSRL) building in the Translational BioImaging Resource (TBIR) section.

Handedness: If you agree, you may be asked to fill out handedness questionnaire. Familiar Handedness Rating includes some questions about hand preferences for you and your family members. These questions are designed to test whether there is a relationship between familial hand preferences and responses during the experimental task. Previous research suggest that there is relationship between family history of handedness and performance on language tasks. This portion of the study will take about 5 minutes.

Cognitive Testing: The study itself requires an initial period of cognitive and neuropsychological testing, followed by 2 or 3 visits to the University of Arizona for neuroimaging procedures. If you agree to participate in the cognitive assessment portion of the study, the cognitive testing typically will require 2 hours, depending on the individual. This may be accomplished in 1 to 2 visits to the Department of Speech, Language and Hearing Sciences, with each visit including 2-3 hours of testing.

The study involves tests of language and memory that provide information about cognitive abilities in adults with or without brain damage. The tests will be conducted in person with the experimenter in an assessment room. During the tests, you may listen to words or sentences or view pictures, and respond by pointing to items or speaking. You may also be asked to complete questionnaires in writing.

Audio recordings will be made of the tests that you perform, but no names or identifying information (i.e. your address or contact information) will be used on any of the recordings. You may be asked to consent to video recordings in some cases, but this is always optional. You will be informed before any recording occurs. You may stop between tasks at any time if you need a break.

Following the cognitive testing, you will be scheduled for 2 or 3 additional visits that will involve neuroimaging assessment (EEG and/or MRI). These visits are described below, but they may not necessarily occur in this order, depending on scheduling. Depending on the exclusion/inclusion criteria, you may participate in one or more of the procedures described below.

Electroencephalography (EEG). During one of the visits to the Department of Speech, Language and Hearing Sciences, you will undergo electroencephalography exam. When brain cells become active, they produce tiny electrical signals that can be measured by special sensors placed on the head. For this procedure, the participant will be seated in a chair, while the net with small sensors embedded in it will be placed on the participant's head. The sensors look like white pieces of plastic about half an inch in diameter. In order to obtain clear recordings, the electrodes are soaked in a clear saline solution before they are placed on the head. A video screen and headphones will be used to conduct language tests while person's brain activity is

recorded. If you become uncomfortable or no longer wish to participate at any time during the experiment, the procedure will be terminated at once.

While wearing the sensor net on your head you will read or listen to the sentences or words. The language stimuli will be presented on the screen in front of you or you will hear them through a speaker/earbuds, and will make a decision about them. You will indicate your decision by pressing a button or answering questions. Your eye movements also may be monitored while you perform some of these tasks. For some parts of this study you will be allowed to rest and no task will be performed. Your participation in this part of the study will last 1-2 hours.

Magnetic Resonance Imaging (MRI): During another visit we may perform an MRI scan (Magnetic Resonance Imaging) of your brain. The MRI scan provides a three-dimensional picture of the structure of the brain. The MRI technique uses magnets and radio waves to construct a picture of the brain on a computer. MRI does not involve radiation (i.e., ionizing radiation) used for an x-ray or computerized tomography (CT) scan. For the MRI procedure, you will be asked to lie on a padded bed that will be moved into a tunnel-like machine for the MRI scan of your brain. It is important that you remain as still as possible during the scan. Movement will not be dangerous to you in any way, but can blur the picture of your brain. The MRI machine is equipped with an intercom system that will allow you to communicate with the MRI technician at any time. When pictures of your brain are acquired the MRI machine makes loud knocking noises, but this is normal. If you feel uncomfortable during the scan and wish to discontinue the procedure, you will be taken out of the machine at your request.

You will be given instructions outside of the MRI scanner about the scanning so that you are comfortable and know what to expect. If you agree to have an MRI or CT SCAN of your brain, you will lie quietly in the scanner, while structural images of your brain are acquired. If you agree to have functional MRI (fMRI) brain scan, you may be asked to read or listen to words or sentences, while pictures of your brain are being acquired. If response is required, you will respond by pressing a button. MRI is noninvasive procedure and measures blood flow to your brain as you perform the task. For some scans you will not need to perform any experimental task and will be allowed to rest throughout the MRI scan. If there is no specific task the MRI scan takes approximately one hour (1 hour). fMRI brain scans may be performed on one or more different occasion. Two scanning sessions may be conducted if MRI involves language task (total 2 hours). You will be asked for your consent to be scanned on each occasion.

The MRI procedure used in this project includes research-oriented scans not typically used in clinical MRI assessments. However, if you are currently unable or unwilling to undergo MRI scanning, it would still be useful for us to analyze any MRI scans that you may have had in the past, either at the University of Arizona or at other hospitals. In this case, you are being asked to grant authorization for our investigators to have access to your MRI or CT data collected previously.

ARIZONA

In order to make sure the MRI procedure is safe, you will be asked to fill out a screening form prior to participating in this study. It is very important that you tell the experimenters in this study if you have any history of:

-Metal fragments in your eyes or face
-Implantation of any electronic devices (such as, but not limited to: cardiac pacemakers, cardiac defibrillators, cochlear implants, or nerve stimulators)
-Surgery on the blood vessels of your brain or the valves of the heart
-Claustrophobia (fear of enclosed places)
-Body piercing or tattoos.

Will video or audio recordings be made of me during the study?
The researchers will make an audio recording during the study so that scoring of responses can be evaluated at a later time by our research team. In some cases, video recordings may be also taken. Such recordings will only be taken if you give your permission to do so. Initial your decision below. **The transcriptions will be done by the researchers, including PA, investigators, research assistant, and the qualified and trained lab personnel.**

_____ I give permission for audio recording to be made of me during my participation in this research study

_____ I do not give permission for audio recording to be made of me during my participation in this research study

_____ I give permission for video recording to be made of me during my participation in this research study

_____ I do not give permission for video recording to be made of me during my participation in this research study

How long will I be in the study?
The participation in the study may require 3-4 visits to the University of Arizona and the Department of Speech, Language, and Hearing Sciences. The visits may be spread out over several days or weeks, depending on your schedule and preferences. The cognitive assessment may require 2-3 hours, depending on the individual. Electroencephalography exam will take 1.5-2 hours, and MRI or fMRI scan may take 1-2 hours (structural MRI = 1h, functional MRI = 1h).

How many people will take part in this study?
Approximately 200-260 participants will be enrolled in this study.

ARIZONA

Can I stop being in the study?

Your participation in this study is voluntary. You may refuse to participate in this study. If you decide to take part in the study, you may leave the study at any time. No matter what decision you make, there will be no penalty to you and you will not lose any of your usual benefits. Your decision will not affect your future relationship with the University of Arizona. If you are a student or employee at the University of Arizona, your decision will not affect your grades or employment status.

What risks or benefits can I expect from being in the study?

The tasks during assessment phase of the study have no more risk that you would come across in everyday life. Although researchers tried to avoid any risks, some of the tasks may be difficult for you and you could find the testing frustrating or upsetting. In some cases, you may find testing to be boring. Every effort will be made by the evaluators to make the process as comfortable as possible.

There are no known health risks associated with the ERP recording procedures. Participants may experience some mild discomfort from sitting still during EEG or from the pressure of the electrode net. However, efforts will be made to position them comfortably and to allow rest periods when needed. In rare cases the skin that is extremely dry may be prone to irritation from the saline solution used in this procedure. If a headache or skin irritation develops, the ERP recording procedure will be discontinued. In very rare cases there may be some mild skin irritation from the electrodes, if the net is tight fitting. However, the pink spots disappear few minutes after the electrode net is removed. For participants who undergo EEG, every attempt will be made to make the process as comfortable as possible.

There are no known risks associated with MRI scanning and our scanner has safety devices. An MRI may cause possible anxiety for people due to the loud noise made by the machine and/or the confined space of the testing area. If anxiety occurs, the scanning procedure will be stopped. Special MRI compatible, headphones or earbuds are used to allow you to hear the experimenter and auditory stimuli, while at the same time they help to reduce the intensity of the scanner noise. For those scanned every effort will be made to make the experience pleasant.

There is some risk of claustrophobia while undergoing MRI scanning. Participants will be able to stop the experiment at any time using the provided squeeze bulb. You can move your feet and say “stop” in a loud voice. An audio system allows communication between operator and the participant during the scan, and will allow the operator to be aware of any distress.
The MRI scan is not associated with any known risks to your health and there is no evidence that there will be either short-term or long-term side effects. MRI does not involve radiation (i.e., ionizing radiation) used for an x-ray or computed tomography (CT) scan. However, it is our policy that if you are a woman of child-bearing age, that you not be pregnant at the time of the MRI scan. MRI presents some safety risks in subjects with contraindications, including pacemakers or other forms of implanted metal. Risks include heating and dislodgment from magnetic forces.

Therefore, you will be carefully screened. Prior to the MRI you will be required to fill out a questionnaire to ensure that there are no contraindications for performing the study. You will not be included in the scanning portion of the study if you meet the exclusionary criteria. The absolute requirements for the MRI scan are that you

1) do NOT have an implanted cardiac pacemaker
2) do NOT have any metal implants, prostheses, pieces of shrapnel, aneurysm clips, or wires in your head or anywhere in the body

If you have a tattoo, there is a very small possibility that you will feel a tingling or burning sensation at the tattoo site.

If you cannot have an MRI due to one of the above concerns, you may be asked to have a CT scan instead. CT scan involves small amount of radiation. Therefore, if you are pregnant or expect to be pregnant you cannot undergo CT scan procedure. This is optional and you will be given an opportunity to consent to this procedure. If you have a history of working with metals we may need to access your orbital x-rays before you undergo MRI for safety reasons. In this case, you are being asked to grant consent for our investigators to have access to your orbital x-rays collected previously. You may be asked to consent to this for safety reasons, but this is always optional. Woman who are pregnant or think that they may be pregnant will not receive MRI or CT scan.

Older participants will complete geriatric depression scale to assess general mood. This assessment takes about 3-5 minutes. For participants showing indication of significant depression we suggest that they visit their family doctor. We will provide a list of resources offered by the Arizona Center on Aging: http://aging.arizona.edu/program/elder-care-resource-interprofessional-providers, Geriatric Mental Health Foundation: http://www.gmhfonline.org/, and Seniors Resource Guide: http://www.seniorsresourceguide.com/directories/Tucson/search.php?region=AZ01&topic=409. You are welcome to ask any questions that you may have.

Benefits: The study will not benefit you specifically, but we hope that the knowledge we gain will contribute to the future care and treatment of patients who have language disorders.

Will my study-related information be kept confidential?
To protect confidentiality participants will be assigned a subject code and this number will be recorded on all test protocols and MRI header files. All behavioral and imaging data will be entered into an electronic database using subject codes rather than names. Your information will be stored in locked file cabinet, in a locked office. The computer files will be protected with a password and this consent form will be filed in an official secure area.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include Principal Investigator and research study personnel.

Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. Representatives of regulatory agencies such as Office of Human Research Protection (OHRP), and entities such as the University of Arizona Human Subject Protection, or the University of Arizona Institutional Review Board may access your records to make sure the study is being run correctly and that the information is collected properly. The institution where this study procedures are being performed (University of Arizona) may also see your information. However, any information that is shared with them will be coded with a number so that they cannot see who you are. Representatives from these entities can see information that has your name on it if they come to the study site to view the study records. If there are any reports about this study, your name will not be in them.

What happens if I am injured because I took part in this study?
Side effects (injury) can happen in any research study. These effects may not be your fault or the fault of the researcher involved. There are no known side effects associated with this study; however, side effects that are not currently known may happen and require care. You don't give up any of your legal rights by signing this form.

If you suffer an injury from participating in this study, you should seek treatment. The University of Arizona has no funds set aside for the payment of treatment expenses for this study. You will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

If you believe that you are injured because of the research or a billed for medical care for injuries that you feel has been caused by the research, you should contact the Principal Investigator Aneta Kielar, Ph.D., at 520-621-5105.

Disclosure of Findings: There is no medical benefit to the MRI scan. If any abnormal findings or results are obtained during your assessments – anything that suggests you may have an undocumented medical problem – you will be informed of this by one of the investigators. In the rare event that the incidental finding requiring medical-follow up is discovered during MRI procedures, there is risk of psychological discomfort associated with receiving this information. To keep this risk to a minimum, the attending neuroradiologist at the University of Arizona Medical Center will be contacted for consultation if there is a question regarding a scan. If new information related to the risks/benefits of the study is obtained, you will be informed.

ARIZONA

What are the costs of taking part in this study?

Aside from your time, there are no costs for taking part in this study. The estimated time required to complete the study will include 2-3 hours for cognitive testing, 1.5-2 hours for EEG study, 1 hour for structural MRI scan and 1 hour for fMRI scan (Total =~5-6h).

Will I be paid for taking part in this study?

You will receive $10 per hour for the language and cognitive assessment procedures, $35 for EEG study, $35 for MRI or CT scan, and $50 for fMRI with language task. We will provide parking, or compensate participants for transportation expenses to the University of Arizona campus, including city bus or taxi fare. In the event of an early withdrawal from the study, reimbursement will be pro-rated to match the level of participation. Compensation for participation in a research study is considered taxable income for you. If your compensation for this research study or a combination of research studies is $600 or more in a calendar year (January to December), you will receive an IRS Form 1099 to report on your taxes. Please note, if you are an employee of UArizona, any compensation from a research study is considerable taxable income. For any compensation or reimbursement you receive, we are required to obtain identifiable information such as your name, address, and, for amounts over $50, Social Security number for financial compliance purposes. This information will be recorded using a dedicated form and will be kept in a separate and secure location than the study data itself. No data with subject identifiers will be released. Your information will be secured in a locked file cabinet in locked office or laboratory while they are active in the data collection of the study phase, and after the study is completed it will be moved to a secure storage. **Participants recruited from the Psychology and Linguistics undergraduate subject pools may receive partial course credit or extra credit for their participation instead of monetary compensation. This is at the discretion of the course instructor.**

When may participation in the study be stopped?

This is a research study and your participation is voluntary. You can choose to discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. No new data will be collected or linked to other data from that point. Upon participant's request any data that has not been processed to remove identifying information will be destroyed. However, we are not able to remove any data that have already been analyzed, processed to remove identifying information, or linked and aggregated with other data.

Will my data be stored for future research?

Anonymized data will be stored at the end of the study for future analysis by the PI and Co-Investigators, but no identifying or personal information will be included. The information from this study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential, and no personal information will be made public. Neither your identity nor any personal information will be available to anyone other than the

ARIZONA

investigators. No personal information will be disclosed in any resulting publication or presentation. Only aggregate data will be reported in the publications.

If there is future collaboration at the University of Arizona or outside institutions, data transfer between institutions or collaborators will be done in a secure manner, without your personal or identifying information. Consent forms will be kept in a separate location than the study data itself. No data with personal identifiers will be released.

If you agree for your anonymized and deidentified data to be used in future research studies you must specify your consent below.

I give my permission for my anonymized data from this study to be used in future studies

_____

The consent for future use of your data is entirely voluntary and may be withdrawn at any time. If you decide now that your data can be kept for future research you can change your mind at any time. Contact the study principal Investigator and let her know that you don't want the data collected to be used, and it will no longer be used for research. If the data has already been used and aggregated with other data it may not be possible to get it back.

Will my data be sold for commercial profits?
Your data will not be sold for commercial profit.

Will I hear back on any results that directly impact me?
The scans that we conduct are not clinical scans. There is no medical benefit from the MRI scan.

You will/will not receive any clinically relevant results discovered about you and/or the general subject population.

Who can answer my questions about the study?
For questions, concerns, or complaints about the study you may contact **Principal Investigator Dr. Aneta Kielar at 520-621-5105.**

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Human Subjects Protection Program Director at 520-626-8630 or online at http://research.arizona.edu/compliance/human-subjects-protection-program.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact the Principal Investigator.

An Institutional Review Board responsible for human subjects research at the University of Arizona reviewed this research project and found it to be acceptable, according to applicable

state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Signing the consent form

I have read (or someone has read to me) this form, and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject	**Signature of subject**	**Date**
Printed name of person authorized to consent for subject (when applicable)	**Signature of person authorized to consent for subject (when applicable)**	**Date**
Relationship to the subject		

Investigator/Research Staff

I have explained the research to the participant or the participant's representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or to the participant's representative.

Printed name of person obtaining consent	**Signature of person obtaining consent**	**Date**

APPENDIX C – SELF-REPORT QUESTIONNAIRE

Language and Neuroimaging Study Screening Questionnaire

Participant ID: _____ Study Number: _____ Date: _____

Demographic Information				
What is your date of birth?		Age:		
Are you male or female?			Male	Female
	If female: Is there any possibility that you are pregnant?		Yes	No
What is your occupation? (Or previous occupation?)				
Are you right-handed or left-handed?			Right	Left
Was English your first language?			Yes	No
	If no: At what age did you first start learning English?			
Do you speak any other languages?			Yes	No
	If yes: Which languages?			
How many total years did you spend in school?				
Have you ever been diagnosed with a learning disability or language problem?			Yes	No
Did you ever fail or skip any grades in school?			Yes	No
Do you think your memory is worse than other people of the same age group as yourself?			Yes	No
Do you think your language ability is worse than other people of the same age group as yourself?			Yes	No
Does this participant meet any EXCLUSION criteria?			**Yes**	**No**

Health Background				
How would you describe your general health?	Excellent	Good	Fair	Poor
Have you ever had any surgeries?			Yes	No
	If yes: Were there any complications?		Yes	No
Have you ever received a heavy blow to the head that resulted in a loss of consciousness or a concussion?			Yes	No
Are you currently diagnosed with any medical conditions such as high or low blood pressure, high or low cholesterol, diabetes, or thyroid disease?			Yes	No

	If yes, list:			
Have you ever been diagnosed with any psychiatric disorders?			Yes	No
Have you ever been treated for anxiety, depression, or any other psychological problems?			Yes	No
Have you ever suffered from seizures or epilepsy?			Yes	No
Have you ever been diagnosed with any neurological disorders?			Yes	No
Have you ever been diagnosed with language disorder (dyslexia, SLI)			Yes	No
	IF STROKE PATIENT:			
	When did you have your stroke?			
	What kind of stroke did you have?			
	What kind of aphasia were you diagnosed with?			
	What kind of treatment did you receive for your aphasia?			
	Are you still receiving treatment?		Yes	No
	IF DEMENTIA PATIENT:			
	What did your doctor diagnose you with?			
	When were you diagnosed?			
	When did you first start noticing symptoms?			
	What kind of symptoms do you have now?			
	Are your symptoms worse now than they were when you were first diagnosed?		Yes	No
	What kind of treatment did you receive?			
	Are you still receiving treatment?		Yes	No
Are you currently taking any daily medications?			Yes	No
Do you wear glasses or contacts?			Yes	No
	If yes: Are they for distance or reading?	Both	Distance	Reading

Do you have any hearing problems?	Yes	No
Do you wear hearing aids	Yes	No
Are you colour blind?	Yes	No
Is your current weight over 200lbs?	Yes	No
If yes: What is your height and weight?		
Do you smoke cigarettes?	Yes	No
Do you drink alcohol?	Yes	No
If yes: Has alcohol ever been a problem for you?	Yes	No
Do you use recreational drugs?	Yes	No
If yes: Have recreational drugs ever been a problem for you?	Yes	No
Does this participant meet any EXCLUSION criteria?	**Yes**	**No**

MRI Safety Clearance			
Have you ever participated in an MRI study at University of Arizona or at the hospital?		Yes	No
Do you ever feel claustrophobic?		Yes	No
Do you have any metal in your body?		Yes	No
Do you have any old metal fillings?		Yes	No
Have you ever been injured by a metallic object or foreign body, like a bullet or shrapnel?		Yes	No
Have you ever worked as a machinist metalworker, or in any other profession or hobby grinding metal?		Yes	No
Do you have any biomedical implants, like a pacemaker, steel rods, pins, clips, or a neurostimulator?		Yes	No
Do you have any body piercings that cannot be removed?		Yes	No
Do you have any tattoos or permanent makeup?		Yes	No
Do you have any jewelry that you cannot take off, like a wedding ring or bracelet?		Yes	No
Is this person MRI safe?	**Needs Medical Clearance**	**Yes**	**No**

APPENDIX D – PSYCHOLINGUISTIC PROPERTIES OF BOSTON NAMING TEST

Table D.1. Pyscholinguistic property values of the Boston Naming Test items

BNT Word	Frequency	Familiarity	AoA	Word Length	PND	SND	Arousal	Valence
Abacus	1.11	4.28	8.69	6.00	0.00	0.30	0.28	0.51
Accordion	1.83	4.74	8.61	7.00	0.00	0.56	0.49	0.60
Acorn	1.58	4.38	5.95	5.00	1.00	0.48	0.20	0.45
Asparagus	1.71	3.87	6.79	9.00	0.00	0.39	0.32	0.47
Beaver	2.39	4.70	5.21	4.00	8.00	0.57	0.34	0.49
Bed	3.98	4.91	2.89	3.00	42.00	0.63	0.17	0.60
Bench	2.69	4.88	4.21	4.00	10.00	0.59	0.29	0.57
Boomerang	1.68		9.79	7.00	0.00	0.44	0.63	0.53
Broom	2.39	4.90	5.50	4.00	15.00	0.46	0.15	0.39
Cactus	2.17	4.79	6.72	6.00	0.00	0.51	0.41	0.44
Camel	2.41	4.74	5.11	5.00	8.00	0.56	0.28	0.54
Canoe	2.26	4.83	6.63	4.00	2.00	0.56	0.30	0.54
Comb	2.49	4.97	5.50	3.00	28.00	0.45	0.12	0.49
Compass	2.32	4.66	8.44	6.00	2.00	0.56	0.31	0.54
Dart	2.00	4.57	7.38	4.00	12.00	0.55	0.61	0.42
Dominoes	1.66	4.73	7.70	7.00	1.00	0.32	0.51	0.59
Escalator	1.83	4.82	7.11	8.00	0.00	0.40	0.53	0.50
Flower	3.07	4.90	3.11	4.00	6.00	0.61	0.33	0.80
Funnel	1.76	4.77	8.44	5.00	8.00	0.49	0.27	0.35
Globe	2.43	4.89	6.50	4.00	5.00	0.62	0.32	0.76
Hammock	1.86	4.67	7.11	5.00	5.00	0.33	0.26	0.67
Hanger	1.85	4.89	6.78	4.00	11.00	0.36	0.52	0.44
Harmonica	1.95	4.38	7.32	9.00	1.00	0.57	0.24	0.85
Harp	2.13	4.76	7.55	4.00	11.00	0.56	0.59	0.62
Helicopter	2.91	4.91	5.26	9.00	0.00	0.60	0.81	0.71
House	4.42	4.98	3.16	3.00	20.00	0.69	0.14	0.59
Igloo	1.20	4.78	5.42	4.00	0.00	0.27	0.30	0.57
Knocker	1.26	4.84	7.89	4.00	14.00	0.18		
Latch	2.00	4.66	8.00	3.00	28.00	0.38	0.26	0.40
Mask	3.00	4.34	4.80	4.00	10.00	0.60	0.49	0.51
Mushroom	2.04	4.82	6.44	6.00	0.00	0.55	0.27	0.49
Muzzle	1.91	4.67	8.44	5.00	8.00	0.55	0.43	0.39
Octopus	2.00	4.84	6.26	7.00	0.00	0.50	0.38	0.71
Palette	1.48	4.76	10.50	5.00	8.00	0.52	0.33	0.59
Pelican	1.95	4.70	8.22	7.00	1.00	0.44	0.39	0.57
Pencil	2.70	4.99	4.06	6.00	1.00	0.53	0.20	0.55
Pretzel	2.01	4.83	5.00	6.00	0.00	0.29	0.32	0.52

Protractor	0.60	4.87	9.75	9.00	1.00	0.19		
Pyramid	2.31	4.67	7.61	7.00	0.00	0.58	0.39	0.74
Racket	2.58	4.87	8.20	5.00	3.00	0.39	0.36	0.52
Racquet	1.26	4.87		5.00	3.00	0.35	0.36	0.52
Rhinoceros	1.59	4.68	6.00	9.00	0.00	0.44	0.66	0.56
Saw	4.31	4.91	5.36	2.00	32.00	0.69	0.54	0.32
Scissors	2.53	4.95	4.50	6.00	8.00	0.44	0.46	0.46
Scroll	2.07	4.56	9.89	5.00	2.00	0.54	0.63	0.38
Seahorse	0.90	4.42	5.83	6.00	1.00	0.31		
Snail	1.96	4.83	5.79	4.00	3.00	0.52	0.10	0.48
Sphinx	1.72	4.66	10.22	6.00	2.00	0.40	0.32	0.60
Stethoscope	1.69	4.74	8.50	9.00	0.00	0.25	0.38	0.43
Stilts	1.32	4.28		6.00	2.00	0.35	0.58	0.44
Tongs	1.61	4.82	7.78	4.00	10.00	0.26	0.46	0.50
Toothbrush	2.41	4.91	4.33	7.00	0.00	0.27	0.33	0.52
Tree	3.52	5.00	3.57	3.00	16.00	0.66	0.12	0.67
Trellis	1.18	3.85	11.17	6.00	0.00	0.26	0.50	0.30
Tripod	1.67	4.27	9.26	6.00	1.00	0.42	0.39	0.41
Unicorn	2.10	4.74	4.83	8.00	0.00	0.49	0.51	0.78
Volcano	2.23	4.72	6.74	7.00	0.00	0.56	0.84	0.24
Wheelchair	2.50	4.88	6.89	7.00	0.00	0.56	0.34	0.24
Whistle	2.90	4.93	5.42	5.00	4.00	0.55	0.55	0.65
Wreath	1.74	4.76	7.06	3.00	25.00	0.43	0.44	0.75
Yoke	1.36	3.59	7.94	3.00	11.00	0.39	0.62	0.28

BNT = Boston Naming Test

REFERENCES

Adelman, J. S., Brown, G. D. A., & Quesada, J. F. (2006). Contextual diversity, not word frequency, determines word-naming and lexical decision times. *Psychological Science*, *17*(9), 814–823. https://doi.org/10.1111/j.1467-9280.2006.01787.x

Adlam, A.-L. R., 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. https://doi.org/10.1080/13554790903405693

Agosta, F., Henry, R. G., Migliaccio, R., Neuhaus, J., Miller, B. L., Dronkers, N. F., Brambati, S., Filippi, M., Ogar, J. M., Wilson, S. M., & Gorno-Tempini, M. L. (2010). Language networks in semantic dementia. *Brain*, *133*(1), 286-299. https://doi.org/10.1093/brain/awp233

Alario, F., Ferrand, L., Laganaro, M., New, B., Frauenfelder, U. H., & Segui, J. (2004). Predictors of picture naming speed. *Behavior Research Methods, Instruments, & Computers*, *36*(1), 140–155. https://doi.org/10.3758/BF03195559

Altarriba, J., & Bauer, L. M. (2004). The distinctiveness of emotion concepts: A comparison between emotion, abstract, and concrete words. *The American journal of psychology*, 389-410. https://doi.org/10.2307/4149007

Alyahya, R. S. W., Halai, A. D., Conroy, P., & Lambon Ralph, M. A. (2020). Mapping psycholinguistic features to the neuropsychological and lesion profiles in aphasia. *Cortex*, *124*, 260–273. https://doi.org/10.1016/j.cortex.2019.12.002

Ash, S., & Grossman, M. (2015). Why study connected speech production. *Cognitive neuroscience of natural language use*, 29-58.

Ash, S., Evans, E., O'Shea, J., Powers, J., Boller, A., Weinberg, D., Haley, J., McMillan, C., Irwin,

D. J., Rascovsky, K., & Grossman, M. (2013). Differentiating primary progressive aphasias in a brief sample of connected speech. *Neurology*, *81*(4), 329-336. https://doi.org/10.1212/WNL.0b013e31829c5d0e

Ash, S., Moore, P., Vesely, L., Gunawardena, D., McMillan, C., Anderson, C., Avants, B., & Grossman, M. (2009). Non-fluent speech in frontotemporal lobar degeneration. *Journal of Neurolinguistics*, *22*(4), 370-383. https://doi.org/10.1016/j.jneuroling.2008.12.001

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. J. (2004). Visual word recognition of single-syllable words. *Journal of experimental psychology: General*, *133*(2), 283. https://doi.org/10.1037/0096-3445.133.2.283

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

Barbieri, E., Litcofsky, K. A., Walenski, M., Chiappetta, B., Mesulam, M. M., & Thompson, C. K. (2021). Online sentence processing impairments in agrammatic and logopenic primary progressive aphasia: Evidence from ERP. *Neuropsychologia*, *151*, 107728. https://doi.org/10.1016/j.neuropsychologia.2020.107728

Barry, C., Hirsh, K. W., Johnston, R. A., & Williams, C. L. (2001). Age of acquisition, word frequency, and the locus of repetition priming of picture naming. *Journal of Memory and Language*, *44*(3), 350–375. https://doi.org/10.1006/jmla.2000.2743

Barry, C., Morrison, C. M., & Ellis, A. W. (1997). Naming the Snodgrass and Vanderwart pictures: Effects of age of acquisition, frequency, and name agreement. *The Quarterly Journal of Experimental Psychology: Section A*, *50*(3), 560–585. https://doi.org/10.1080/783663595

Bastiaanse, R., Wieling, M., & Wolthuis, N. (2016). The role of frequency in the retrieval of nouns

and verbs in aphasia. *Aphasiology*, *30*(11), 1221-1239. https://doi.org/10.1080/02687038.2015.1100709

Beeson, P. M., Rising, K., Kim, E. S., & Rapcsak, S. Z. (2010). A treatment sequence for phonological alexia/agraphia. *Journal of Speech, Language, and Hearing Research*, *53*(2), 450-468. https://doi.org/10.1044/1092-4388(2009/08-0229)

Beeson, P. M., Rising, K., Sachs, A., & Rapcsak, S. Z. (2022). Common predictors of spoken and written language performance in aphasia, alexia, and agraphia. *Frontiers in Human Neuroscience*, *16*, 719. https://doi.org/10.3389/fnhum.2022.1025468

Belke, E., Brysbaert, M., Meyer, A. S., & Ghyselinck, M. (2005). Age of acquisition effects in picture naming: Evidence for a lexical-semantic competition hypothesis. *Cognition*, *96*(2), B45–B54. https://doi.org/10.1016/j.cognition.2004.11.006

Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997). Verb retrieval in aphasia: Characterizing single word impairments. *Brain and language*, *56*(1), 68-106. https://doi.org/10.1006/brln.1997.1727

Biesbroek, J. M., van Zandvoort, M. J., Kappelle, L. J., Velthuis, B. K., Biessels, G. J., & Postma, A. (2016). Shared and distinct anatomical correlates of semantic and phonemic fluency revealed by lesion-symptom mapping in patients with ischemic stroke. *Brain Structure and Function*, *221*, 2123-2134. https://doi.org/10.1007/s00429-015-1033-8

Bird, H., & Franklin, S. (1996). Cinderella revisited: A comparison of fluent and non-fluent aphasic speech. *Journal of neurolinguistics*, *9*(3), 187-206. https://doi.org/10.1016/0911-6044(96)00006-1

Bird, H., Franklin, S., & Howard, D. (2001). Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments, & Computers*, *33*(1), 73-79. https://doi.org/10.3758/BF03195349

Bird, H., Howard, D., & Franklin, S. (2000). Why is a verb like an inanimate object? Grammatical category and semantic category deficits. *Brain and language*, *72*(3), 246-309. https://doi.org/10.1006/brln.2000.2292

Bird, H., Lambon Ralph, M. A., Patterson, K., & Hodges, J. R. (2000). The rise and fall of frequency and imageability: Noun and verb production in semantic dementia. *Brain and language*, *73*(1), 17-49. https://doi.org/10.1006/brln.2000.2293

Bonin, P., Barry, C., Méot, A., & Chalard, M. (2004). The influence of age of acquisition in word reading and other tasks: A never ending story?. *Journal of Memory and language*, *50*(4), 456-476. https://doi.org/10.1016/j.jml.2004.02.001

Bonin, P., Chalard, M., Méot, A., & Fayol, M. (2002). The determinants of spoken and written picture naming latencies. *British Journal of Psychology*, *93*(1), 89–114. https://doi.org/10.1348/000712602162463

Bormann, T. (2011). The role of lexical-semantic neighborhood in object naming: Implications for models of lexical access. *Frontiers in psychology*, *2*, 127. https://doi.org/10.3389/fpsyg.2011.00127

Boyle, M., & Coelho, C. A. (1995). Application of semantic feature analysis as a treatment for aphasic dysnomia. *American Journal of Speech-Language Pathology*, *4*(4), 94-98. https://doi.org/10.1044/1058-0360.0404.94

Brambati, S. M., Ogar, J., Neuhaus, J., Miller, B. L., & Gorno-Tempini, M. L. (2009). Reading disorders in primary progressive aphasia: a behavioral and neuroimaging

study. *Neuropsychologia*, *47*(8-9), 1893-1900. https://doi.org/10.1016/j.neuropsychologia.2009.02.033

Braun, E. J., & Kiran, S. (2022). Stimulus-and Person-Level Variables Influence Word Production and Response to Anomia Treatment for Individuals With Chronic Poststroke Aphasia. *Journal of Speech, Language, and Hearing Research*, *65*(10), 3854–3872. https://doi.org/10.1044/2022_JSLHR-21-00527

Brown, G. D., & Watson, F. L. (1987). First in, first out: Word learning age and spoken word frequency as predictors of word familiarity and word naming latency. *Memory & cognition*, *15*(3), 208-216. https://doi.org/10.3758/BF03197718

Bryant, L., Ferguson, A., & Spencer, E. (2016). Linguistic analysis of discourse in aphasia: A review of the literature. *Clinical linguistics & phonetics*, *30*(7), 489-518. https://doi.org/10.3109/02699206.2016.1145740

Bryant, L., Spencer, E., & Ferguson, A. (2017). Clinical use of linguistic discourse analysis for the assessment of language in aphasia. *Aphasiology*, *31*(10), 1105-1126. https://doi.org/10.1080/02687038.2016.1239013

Brysbaert, M., & Ellis, A. W. (2016). Aphasia and age of acquisition: are early-learned words more resilient?. *Aphasiology*, *30*(11), 1240-1263. https://doi.org/10.1080/02687038.2015.1106439

Brysbaert, M., & Ghyselinck, M. (2006). The effect of age of acquisition: Partly frequency related, partly frequency independent. *Visual Cognition*, *13*(7–8), 992–1011. https://doi.org/10.1080/13506280544000165

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency

measure for American English. *Behavior research methods*, *41*(4), 977-990. https://doi.org/10.3758/BRM.41.4.977

Brysbaert, M., Keuleers, E., & Mandera, P. (2014). A plea for more interactions between psycholinguistics and natural language processing research. *Computational Linguistics in the Netherlands Journal*, *4*, 209-222.

Brysbaert, M., Mandera, P., & Keuleers, E. (2018). The word frequency effect in word processing: An updated review. *Current Directions in Psychological Science*, *27*(1), 45–50. https://doi.org/10.1177/0963721417727521

Buchanan, T. W., Etzel, J. A., Adolphs, R., & Tranel, D. (2006). The influence of autonomic arousal and semantic relatedness on memory for emotional words. *International journal of psychophysiology*, *61*(1), 26-33. https://doi.org/10.1016/j.ijpsycho.2005.10.022

Catani, M., Mesulam, M. M., Jakobsen, E., Malik, F., Martersteck, A., Wieneke, C., Thompson, C. K., Thiebaut de Schotten, M., Dell'Acqua, F., Weintraub, S., & Rogalski, E. (2013). A novel frontal pathway underlies verbal fluency in primary progressive aphasia. *Brain*, *136*(8), 2619-2628. https://doi.org/10.1093/brain/awt163

Chang, Y.-N., Monaghan, P., & Welbourne, S. (2019). A computational model of reading across development: Effects of literacy onset on language processing. *Journal of Memory and Language*, *108*, 104025. https://doi.org/10.1016/j.jml.2019.05.003

Charles, D., Olm, C., Powers, J., Ash, S., Irwin, D. J., McMillan, C. T., Rascovsky, K., & Grossman, M. (2014). Grammatical comprehension deficits in non-fluent/agrammatic primary progressive aphasia. *Journal of Neurology, Neurosurgery & Psychiatry*, *85*(3), 249-256. https://doi.org/10.1136/jnnp-2013-305749

Chen, J., & Chang, H. (2023). Assessing lexical psycholinguistic properties in Mandarin discourse

production by patients with aphasia. In *Workshop on Chinese Lexical Semantics* (pp. 11-22). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-97-0583-2_2

Cherney, L. R., Halper, A. S., Holland, A. L., & Cole, R. (2008). Computerized script training for aphasia: Preliminary results. *American Journal of Speech-Language Pathology*, *17*(1), 19-34. https://doi.org/10.1044/1058-0360(2008/003)

Chwilla, D. J. (2022). Context effects in language comprehension: The role of emotional state and attention on semantic and syntactic processing. *Frontiers in human neuroscience*, *16*, 1014547. https://doi.org/10.3389/fnhum.2022.1014547

Citron, F. M. (2012). Neural correlates of written emotion word processing: a review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and language*, *122*(3), 211-226. https://doi.org/10.1016/j.bandl.2011.12.007

Collina, S., Marangolo, P., & Tabossi, P. (2001). The role of argument structure in the production of nouns and verbs. *Neuropsychologia*, *39*(11), 1125-1137. https://doi.org/10.1016/S0028-3932(01)00058-6

Colombo, L., & Burani, C. (2002). The influence of age of acquisition, root frequency, and context availability in processing nouns and verbs. *Brain and Language*, *81*(1-3), 398-411. https://doi.org/10.1006/brln.2001.2533

Conca, F., Esposito, V., Giusto, G., Cappa, S. F., & Catricalà, E. (2022). Characterization of the logopenic variant of primary progressive aphasia: a systematic review and meta-analysis. *Ageing Research Reviews*, *82*, 101760. https://doi.org/10.1016/j.arr.2022.101760

Cortese, M. J., & Khanna, M. M. (2007). Age of acquisition predicts naming and lexical-decision performance above and beyond 22 other predictor variables: An analysis of 2,342

words. *Quarterly Journal of Experimental Psychology*, *60*(8), 1072-1082. https://doi.org/10.1080/17470210701315467

Coyle-Gilchrist, I. T., Dick, K. M., Patterson, K., Vázquez Rodríquez, P., Wehmann, E., Wilcox, A., Lansdall, C. J.., Dawson, K. E., Wiggins, J., Mead, S., Brayne, C., Rowe, J. B. (2016). Prevalence, characteristics, and survival of frontotemporal lobar degeneration syndromes. *Neurology*, *86*(18), 1736-1743. https://doi.org/10.1212/WNL.0000000000002638

Cree, G. S., McRae, K., & McNorgan, C. (1999). An attractor model of lexical conceptual processing: Simulating semantic priming. *Cognitive Science*, *23*(3), 371-414. https://doi.org/10.1207/s15516709cog2303_4

Croot, K., Ballard, K., Leyton, C. E., & Hodges, J. R. (2012). Apraxia of speech and phonological errors in the diagnosis of nonfluent/agrammatic and logopenic variants of primary progressive aphasia. https://doi.org/10.1044/1092-4388(2012/11-0323)

Cummings, L. (2019). Narrating the Cinderella story in adults with primary progressive aphasia. In *Further advances in pragmatics and philosophy: Part 2 theories and applications* (pp. 301-329). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-00973-1_18

de la Sablonnière, J., Tastevin, M., Lavoie, M., & Laforce Jr, R. (2021). Longitudinal changes in cognition, behaviours, and functional abilities in the three main variants of primary progressive aphasia: a literature review. *Brain Sciences*, *11*(9), 1209. https://doi.org/10.3390/brainsci11091209

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). Examiner's Manual for the Delis-Kaplan Executive Function System. In *Child Neuropsychology*, *10*(2).

http://doi.org/10.1080/09297040490911140

Dell, G. S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and cognitive processes*, *5*(4), 313-349. https://doi.org/10.1080/01690969008407066

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

Duffy, J. R. (2006). Apraxia of speech in degenerative neurologic disease. *Aphasiology*, *20*(6), 511-527. https://doi.org/10.1080/02687030600597358

Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.

Dymarska, A., Connell, L., & Banks, B. (2023). More is not necessarily better: How different aspects of sensorimotor experience affect recognition memory for words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *49*(10), 1572. https://doi.org/10.1037/xlm0001265

Edmonds, L. A. (2016). A review of Verb Network Strengthening Treatment: Theory, methods, results, and clinical implications. *Topics in Language Disorders*, *36*(2), 123-135. https://doi.org/10.1097/TLD.0000000000000088

Edmonds, L. A., Nadeau, S. E., & Kiran, S. (2009). Effect of Verb Network Strengthening Treatment (VNeST) on lexical retrieval of content words in sentences in persons with aphasia. *Aphasiology*, *23*(3), 402-424. https://doi.org/10.1080/02687030802291339

Ellis, A. W., & Lambon Ralph, M. A. (2000). Age of acquisition effects in adult lexical processing reflect loss of plasticity in maturing systems: insights from connectionist networks. *Journal*

of Experimental Psychology: Learning, memory, and cognition, *26*(5), 1103. https://doi.org/10.1037/0278-7393.26.5.1103

Ellis, A. W., & Morrison, C. M. (1998). Real age-of-acquisition effects in lexical retrieval. *Journal of experimental psychology: learning, Memory, and cognition*, *24*(2), 515. https://doi.org/10.1037/0278-7393.24.2.515

Ferretti, T. R., McRae, K., & Hatherell, A. (2001). Integrating verbs, situation schemas, and thematic role concepts. *Journal of Memory and Language*, *44*(4), 516-547. https://doi.org/10.1006/jmla.2000.2728

Forbes-McKay, K. E., Ellis, A. W., Shanks, M. F., & Venneri, A. (2005). The age of acquisition of words produced in a semantic fluency task can reliably differentiate normal from pathological age related cognitive decline. *Neuropsychologia*, *43*(11), 1625-1632. https://doi.org/10.1016/j.neuropsychologia.2005.01.008

Forbes, M. M., Fromm, D., & MacWhinney, B. (2012, August). AphasiaBank: A resource for clinicians. *Seminars in speech and language*, 33(3), 217-222. https://doi.org/10.1055/s-00321320041

Fraser, K. C., Meltzer, J. A., Graham, N. L., Leonard, C., Hirst, G., Black, S. E., & Rochon, E. (2014). Automated classification of primary progressive aphasia subtypes from narrative speech transcripts. *Cortex*, *55*, 43-60. https://doi.org/10.1016/j.cortex.2012.12.006

Gagnon, D. A., Schwartz, M. F., Martin, N., Dell, G. S., & Saffran, E. M. (1997). The origins of formal paraphasias in aphasics' picture naming. *Brain and Language*, *59*(3), 450-472. https://doi.org/10.1006/brln.1997.1792

Gahl, S., Yao, Y., & Johnson, K. (2012). Why reduce? Phonological neighborhood density and phonetic reduction in spontaneous speech. *Journal of memory and language*, *66*(4), 789-806.

https://doi.org/10.1016/j.jml.2011.11.006

Gallée, J., Cordella, C., Fedorenko, E., Hochberg, D., Touroutoglou, A., Quimby, M., & Dickerson, B. C. (2021). Breakdowns in informativeness of naturalistic speech production in primary progressive aphasia. *Brain sciences*, *11*(2), 130. https://doi.org/10.3390/brainsci11020130

Gao, C., Shinkareva, S. V., & Desai, R. H. (2023). Scope: The south carolina psycholinguistic metabase. *Behavior Research Methods*, *55*(6), 2853-2884. https://doi.org/10.3758/s13428-022-01934-0

Gathercole, S. E., Willis, C. S., Baddeley, A. D., & Emslie, H. (1994). The children's test of nonword repetition: A test of phonological working memory. *Memory*, *2*(2), 103–127. https://doi.org/10.1080/09658219408258940

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. *BBN report; no. 4854*.

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. https://doi.org/10.1037/0278-7393.24.2.267

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of experimental psychology: General*, *113*(2), 256. https://doi.org/10.1037/0278-7393.24.2.267

Ghasisin, L., Yadegari, F., Rahgozar, M., Nazari, A., & Rastegarianzade, N. (2015). A new set of 272 pictures for psycholinguistic studies: Persian norms for name agreement, image agreement, conceptual familiarity, visual complexity, and age of acquisition. *Behavior Research Methods*, *47*(4), 1148–1158. https://doi.org/10.3758/s13428-014-0537-0

Ghyselinck, M., Lewis, M. B., & Brysbaert, M. (2004). Age of acquisition and the cumulative-frequency hypothesis: A review of the literature and a new multi-task investigation. *Acta Psychologica*, *115*(1), 43–67. https://doi.org/10.1016/j.actpsy.2003.11.002

Giannini, L. A., Irwin, D. J., McMillan, C. T., Ash, S., Rascovsky, K., Wolk, D. A., Van Deerlin, V. M., Lee E. B., Trojanowski, J. Q., & Grossman, M. (2017). Clinical marker for Alzheimer disease pathology in logopenic primary progressive aphasia. *Neurology*, *88*(24), 2276-2284. https://doi.org/10.1212/WNL.0000000000004034

Goldrick, M., & Rapp, B. (2007). Lexical and post-lexical phonological representations in spoken production. *Cognition*, *102*(2), 219-260. https://doi.org/10.1016/j.cognition.2005.12.010

Goñi, J., Arrondo, G., Sepulcre, J., Martincorena, I., Vélez de Mendizábal, N., Corominas-Murtra, B., Bejarano, B., Ardanza-Trevijano, S., Peraita, H., Wall, D. P., & Villoslada, P. (2011). The semantic organization of the animal category: evidence from semantic verbal fluency and network theory. *Cognitive processing*, *12*, 183-196. https://doi.org/10.1007/s10339-010-0372-x

Gordon, J. K. (2002). Phonological neighborhood effects in aphasic speech errors: Spontaneous and structured contexts. *Brain and language*, *82*(2), 113-145. https://doi.org/10.1016/S0093-934X(02)00001-9

Gorno-Tempini, M. L., Brambati, S. M., Ginex, V., Ogar, J., Dronkers, N. F., Marcone, A., Perani, D., Garibotto, V., Cappa, S. F. & Miller, B. L. (2008). The logopenic/phonological variant of primary progressive aphasia. *Neurology*, *71*(16), 1227-1234. https://doi.org/10.1212/01.wnl.0000320506.79811.da

Gorno-Tempini, M. L., Hillis, A. E., Weintraub, S., Kertesz, A., Mendez, M., Cappa, S. F., Ogar,

J. M., Rohrer, J. D., Black, S., Boeve, B. F., Manes, F., Dronkers, N. F., Vandenberghe, R., Rascovsky, K., Patterson, K., Miller, B. L., Knopman, D. S., Hodges, J. R., Mesulam, M. M., & Grossman, M. (2011). Classification of primary progressive aphasia and its variants. *Neurology*, *76*(11), 1006–1014. https://doi.org/10.1212/WNL.0b013e31821103e6

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. https://doi.org/10.1162/jocn.2007.19.4.617

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. https://doi.org/10.1162/jocn.2007.19.4.617

Grossman, M. (2010). Primary progressive aphasia: clinicopathological correlations. *Nature Reviews Neurology*, *6*(2), 88-97. https://doi.org/10.1038/nrneurol.2009.216

Grossman, M. (2012). The non-fluent/agrammatic variant of primary progressive aphasia. *The Lancet Neurology*, *11*(6), 545-555. https://doi.org/10.1016/S1474-4422(12)70099-6

Grossman, M., & Ash, S. (2004). Primary progressive aphasia: a review. *Neurocase*, *10*(1), 3-18. https://doi.org/10.1080/13554790490960440

Grossman, M., Mickanin, J., Onishi, K., Hughes, E., D'Esposito, M., Ding, X. S., Alavi, A., & Reivich, M. (1996). Progressive nonfluent aphasia: language, cognitive, and PET measures contrasted with probable Alzheimer's disease. *Journal of cognitive neuroscience*, *8*(2), 135-154. https://doi.org/10.1162/jocn.1996.8.2.135

Hameau, S., Biedermann, B., Fieder, N., & Nickels, L. (2020). Investigation of the effects of semantic neighbours in aphasia: A facilitated naming study. *Aphasiology*, *34*(7), 840-864. https://doi.org/10.1080/02687038.2019.1652241

Hameau, S., Nickels, L., & Biedermann, B. (2019). Effects of semantic neighbourhood density on spoken word production. *Quarterly Journal of Experimental Psychology*, *72*(12), 2752-2775. https://doi.org/10.1177/1747021819859850

Hannay, M., & Hengeveld, K. (2009). Functional discourse grammar: pragmatic aspects. In *Grammar, meaning and pragmatics* (pp. 91-116). John Benjamins Publishing Company. https://doi.org/10.1075/hoph.5.06han

Harmon, T. G., Nielsen, C., Loveridge, C., & Williams, C. (2023). Effects of positive and negative emotions on picture naming for people with mild-to-moderate aphasia: A preliminary investigation. *Journal of Speech, Language, and Hearing Research*, *65*(3), 1025-1043. https://doi.org/10.1044/2021_JSLHR-21-00190

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford publications.

Heikkola, L. M., Kuzmina, E., & Jensen, B. U. (2021). Predictors of object naming in aphasia: does cognitive control mediate the effects of psycholinguistic variables? *Aphasiology*, 1–18. https://doi.org/10.1080/02687038.2021.1950607

Henderson, S. K., Peterson, K. A., Patterson, K., Lambon Ralph, M. A., & Rowe, J. B. (2023). Verbal fluency tests assess global cognitive status but have limited diagnostic differentiation: evidence from a large-scale examination of six neurodegenerative diseases. *Brain Communications*, *5*(2), fcad042. https://doi.org/10.1093/braincomms/fcad042

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance

following focal cortical lesions. *Neuropsychology*, *18*(2), 284. https://doi.org/10.1037/0894-4105.18.2.284

Henry, M. L., & Gorno-Tempini, M. L. (2010). The logopenic variant of primary progressive aphasia. *Current Opinion in Neurology*, *23*(6), 633. https://doi.org/10.1097/WCO.0b013e32833fb93e

Henry, M. L., & Grasso, S. M. (2018). Assessment of individuals with primary progressive aphasia. *Seminar in Speech and Language*, *39*(03), 231-241. https://doi.org/10.1055/s-0038-1660782

Henry, M. L., Wilson, S. M., Babiak, M. C., Mandelli, M. L., Beeson, P. M., Miller, Z. A., & Gorno-Tempini, M. L. (2016). Phonological processing in primary progressive aphasia. *Journal of Cognitive Neuroscience*, *28*(2), 210–222. https://doi.org/10.1162/jocn_a_00901

Herbert, R., Hickin, J., Howard, D., Osborne, F., & Best, W. (2008). Do picture-naming tests provide a valid assessment of lexical retrieval in conversation in aphasia?. *Aphasiology*, *22*(2), 184-203. https://doi.org/10.1080/02687030701262613

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. https://doi.org/10.1016/j.cognition.2003.10.011

Himmanen, S. A., Gentles, K., & Sailor, K. (2003). Rated familiarity, visual complexity, and image agreement and their relation to naming difficulty for items from the Boston Naming Test. *Journal of Clinical and Experimental Neuropsychology*, *25*(8), 1178–1185. https://doi.org/10.1076/jcen.25.8.1178.16729

Hinojosa, J. A., Méndez-Bértolo, C., Carretié, L., & Pozo, M. A. (2010). Emotion modulates language production during covert picture naming. *Neuropsychologia*, *48*(6), 1725–1734.

https://doi.org/10.1016/j.neuropsychologia.2010.02.020

Hirsh, K. W., & Ellis, A. W. (1994). Age of acquisition and lexical processing in aphasia: A case study. *Cognitive Neuropsychology*, *11*(4), 435-458. https://doi.org/10.1080/02643299408251981

Hirsh, K. W., & Funnell, E. (1995). Those old, familiar things: Age of acquisition, familiarity and lexical access in progressive aphasia. *Journal of neurolinguistics*, *9*(1), 23-32. https://doi.org/10.1016/0911-6044(95)00003-8

Hodges, J. R., Patterson, K., Oxbury, S., & Funnell, E. (1992). Semantic dementia: Progressive fluent aphasia with temporal lobe atrophy. *Brain*, *115*(6), 1783-1806. https://doi.org/10.1093/brain/115.6.1783

Hoffman, P., Lambon Ralph, M. A., & Rogers, T. T. (2013). Semantic diversity: A measure of semantic ambiguity based on variability in the contextual usage of words. *Behavior research methods*, *45*(3), 718-730. https://doi.org/10.3758/s13428-012-0278-x

Hoffman, P., Meteyard, L., & Patterson, K. (2014). Broadly speaking: Vocabulary in semantic dementia shifts towards general, semantically diverse words. *Cortex*, *55*, 30–42. https://doi.org/10.1016/j.cortex.2012.11.004

Holmes, S. J., Jane Fitch, F., & Ellis, A. W. (2006). Age of acquisition affects object recognition and naming in patients with Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, *28*(6), 1010-1022. https://doi.org/10.1080/13803390591004392

Howard, D., & Gatehouse, C. (2006). Distinguishing semantic and lexical word retrieval deficits in people with aphasia. *Aphasiology*, *20*(9), 921-950. https://doi.org/10.1080/02687030600782679

Ihssen, N., Heim, S., & Keil, A. (2007). The costs of emotional attention: Affective processing

inhibits subsequent lexico-semantic analysis. *Journal of Cognitive Neuroscience*, *19*(12), 1932–1949. https://doi.org/10.1162/jocn.2007.19.12.1932

Illán-Gala, I., Lorca-Puls, D. L., Tee, B. L., Ezzes, Z., de Leon, J., Miller, Z. A., Rubio-Guerra, S., Santos-Santos, M., Gómez-Andrés, D., Grinberg, L. T., Spina, S., Kramer, J. H., Wauters, L. D., Henry, M. L., Boxer, A. L., Rosen, H. J., Miller, B. L., Seeley, W. W., Mandelli, M. L., & Gorno-Tempini, M. L. (2024). Clinical dimensions along the non-fluent variant primary progressive aphasia spectrum. *Brain*, *147*(4), 1511-1525. https://doi.org/10.1093/brain/awad396

Indefrey, P., & Cutler, A. (2004). Prelexical and lexical processing in listening. In *The cognitive neurosciences III.* (pp. 759-774). MIT Press.

Jebahi, F., & Kielar, A. (2024). The relationship between semantics, phonology, and naming performance in aphasia: a structural equation modeling approach. *Cognitive Neuropsychology*, *41*(3-4), 113-128. https://doi.org/10.1080/02643294.2024.2373842

Jebahi, F., & Kielar, A. (2025). Leveraging Thematic Relationships Between Verbs and Nouns for Noun Retrieval Treatment in Logopenic Primary Progressive Aphasia: A Case Series. *American Journal of Speech-Language Pathology*, 1-18. https://doi.org/10.1044/2025_AJSLP-25-00107

Jebahi, F., Nickels, K. V., & Kielar, A. (2024a). Predicting confrontation naming in the logopenic variant of primary progressive aphasia. *Aphasiology*, *38*(4), 635-666. https://doi.org/10.1080/02687038.2023.2221998

Jebahi, F., Nickels, K. V., & Kielar, A. (2024b). Patterns of performance on the animal fluency task in logopenic variant of primary progressive aphasia: A reflection of phonological and

semantic skills. *Journal of Communication Disorders*, *108*, 106405. https://doi.org/10.1016/j.jcomdis.2024.106405

Jefferies, E., & Lambon Ralph, M. A. (2006). Semantic impairment in stroke aphasia versus semantic dementia: a case-series comparison. *Brain*, *129*(8), 2132-2147. https://doi.org/10.1093/brain/awl153

Jescheniak, J. D., & Levelt, W. J. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of experimental psychology: learning, Memory, and cognition*, *20*(4), 824. https://doi.org/10.1037/0278-7393.20.4.824

Juhasz, B. J. (2005). Age-of-acquisition effects in word and picture identification. *Psychological Bulletin*, *131*(5), 684. https://doi.org/10.1037/0033-2909.131.5.684

Jurafsky, D. (2003). Probabilistic modeling in psycholinguistics: Linguistic comprehension and production. *Probabilistic linguistics*, *21*, 1-30.

Kamath, V., Sutherland, E. R., & Chaney, G. A. (2020). A meta-analysis of neuropsychological functioning in the logopenic variant of primary progressive aphasia: Comparison with the semantic and non-fluent variants. *Journal of the International Neuropsychological Society*, *26*(3), 322-330. https://doi.org/10.1017/S1355617719001115

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston naming test*.

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

Kendall, D. L., & Nadeau, S. E. (2016). The phonomotor approach to treating phonological-based language deficits in people with aphasia. *Topics in Language Disorders*, *36*(2), 109-122. https://doi.org/10.1097/TLD.0000000000000085

Kertesz, A. (2007). *Western Aphasia Battery–Revised*. The Psychological Corporation. https://doi.org/10.1037/t15168-000

Khanna, M. M., & Cortese, M. J. (2021). How well imageability, concreteness, perceptual strength, and action strength predict recognition memory, lexical decision, and reading aloud performance. *Memory*, *29*(5), 622-636. https://doi.org/10.1080/09658211.2021.1924789

Kielar, A., Shah-Basak, P. P., Patterson, D. K., Jokel, R., & Meltzer, J. A. (2022). Electrophysiological abnormalities as indicators of early-stage pathology in Primary Progressive Aphasia (PPA): A case study in semantic variant PPA. *Neurocase*, *28*(1), 110-122. https://doi.org/10.1080/13554794.2022.2039207

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. https://doi.org/10.1080/02643290701674851

Kousta, S. T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, *112*(3), 473-481. https://doi.org/10.1016/j.cognition.2009.06.007

Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: valence and arousal affect word recognition. *Journal of Experimental Psychology: General*, *143*(3), 1065. https://doi.org/10.1037/a0035669

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods*, *44*(4), 978–990. https://doi.org/10.3758/s13428-012-0210-4

Lambon Ralph, M. A., & Ehsan, S. (2006). Age of acquisition effects depend on the mapping

between representations and the frequency of occurrence: Empirical and computational evidence. *Visual Cognition*. https://doi.org/10.1080/13506280544000110

Lambon Ralph, M. A., Graham, K. S., Ellis, A. W., & Hodges, J. R. (1998). Naming in semantic dementia—what matters? *Neuropsychologia*, *36*(8), 775–784. https://doi.org/10.1016/S0028-3932(97)00169-3

Lambon Ralph, M. A., Moriarty, L., & Sage, K. (2002). Anomia is simply a reflection of semantic and phonological impairments: Evidence from a case-series study. *Aphasiology*, *16*(1–2), 56–82. https://doi.org/10.1080/02687040143000448

Lambon Ralph, M. A., Moriarty, L., & Sage, K. (2002). Anomia is simply a reflection of semantic and phonological impairments: Evidence from a case-series study. *Aphasiology*, *16*(1-2), 56-82. https://doi.org/10.1080/02687040143000448

Lampe, L. F., Hameau, S., Fieder, N., & Nickels, L. (2021). Effects of semantic variables on word production in aphasia. *Cortex*, *141*, 363–402. https://doi.org/10.1016/j.cortex.2021.02.020

Lanzi, A. M., Saylor, A. K., Fromm, D., Liu, H., MacWhinney, B., & Cohen, M. L. (2023). DementiaBank: Theoretical rationale, protocol, and illustrative analyses. *American Journal of Speech-Language Pathology*, *32*(2), 426-438. https://doi.org/10.1044/2022_AJSLP-22-00281

Larsen, R. J., Mercer, K. A., Balota, D. A., & Strube, M. J. (2008). Not all negative words slow down lexical decision and naming speed: importance of word arousal. *Emotion*, *8*(4), 445–452. https://doi.org/10.1037/1528-3542.8.4.445

Lavoie, M., Black, S. E., Tang-Wai, D. F., Graham, N. L., Stewart, S., Leonard, C., & Rochon, E. (2021). Description of connected speech across different elicitation tasks in the logopenic variant of primary progressive aphasia. *International journal of language & communication*

disorders, *56*(5), 1074-1085. https://doi.org/10.1111/1460-6984.12660

Leach, L. (2000). *The Kaplan–Baycrest neurocognitive assessment (KBNA): TEST manual*. San Antonio, TX: Harcourt Assessment.

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and brain sciences*, *22*(1), 1-38.

Lewellen, M. J., Goldinger, S. D., Pisoni, D. B., & Greene, B. G. (1993). Lexical familiarity and processing efficiency: individual differences in naming, lexical decision, and semantic categorization. *Journal of Experimental Psychology: General*, *122*(3), 316. https://doi.org/10.1037/0096-3445.122.3.316

Leyton, C. E., Hodges, J. R., McLean, C. A., Kril, J. J., Piguet, O., & Ballard, K. J. (2015). Is the logopenic-variant of primary progressive aphasia a unitary disorder? *Cortex*, *67*, 122–133. https://doi.org/10.1016/j.cortex.2015.03.011

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and hearing*, *19*(1), 1-36. https://doi.org/10.1016/j.cortex.2015.03.011

Mack, J. E., Chandler, S. D., Meltzer-Asscher, A., Rogalski, E., Weintraub, S., Mesulam, M. M., & Thompson, C. K. (2015). What do pauses in narrative production reveal about the nature of word retrieval deficits in PPA?. *Neuropsychologia*, *77*, 211-222. https://doi.org/10.1016/j.neuropsychologia.2015.08.019

Mack, J. E., Cho-Reyes, S., Kloet, J. D., Weintraub, S., Mesulam, M.-M., & Thompson, C. K. (2013). Phonological facilitation of object naming in agrammatic and logopenic primary progressive aphasia (PPA). *Cognitive Neuropsychology*, *30*(3), 172–193. https://doi.org/10.1080/02643294.2013.835717

Macoir, J., Hudon, C., Tremblay, M. P., Laforce, R. J., & Wilson, M. A. (2019). The contribution of semantic memory to the recognition of basic emotions and emotional valence: Evidence from the semantic variant of primary progressive aphasia. *Social neuroscience*, *14*(6), 705-716. https://doi.org/10.1080/17470919.2019.1577295

Macoir, J., Légaré, A., & Lavoie, M. (2021). Contribution of the cognitive approach to language assessment to the differential diagnosis of primary progressive aphasia. *Brain sciences*, *11*(6), 815. https://doi.org/10.3390/brainsci11060815

MacWhinney, B., Fromm, D., Holland, A., Forbes, M., & Wright, H. (2010). Automated analysis of the Cinderella story. *Aphasiology*, *24*(6-8), 856-868. https://doi.org/10.1080/02687030903452632

Madhavan, A., Whitwell, J. L., Weigand, S. D., Duffy, J. R., Strand, E. A., Machulda, M. M., Tosakulwong, N., Senjem M. L., Gunter, J. L., Lowe, V. J., Petersen, R.C., Jack, C. R., & Josephs, K. A. (2013). FDG PET and MRI in logopenic primary progressive aphasia versus dementia of the Alzheimer's type. *PloS one*, *8*(4), e62471. https://doi.org/10.1371/journal.pone.0062471

Mandelli, M. L., Caverzasi, E., Binney, R. J., Henry, M. L., Lobach, I., Block, N., Amirbekian, B., Dronkers, N., Miller, B. L., Henry, R. G., & Gorno-Tempini, M. L. (2014). Frontal white matter tracts sustaining speech production in primary progressive aphasia. *Journal of Neuroscience*, *34*(29), 9754-9767. https://doi.org/10.1523/JNEUROSCI.3464-13.2014

Mandelli, M. L., Vitali, P., Santos, M., Henry, M., Gola, K., Rosenberg, L., Dronkers, N., Miller, B. L., Seeley, W. W., & Gorno-Tempini, M. L. (2016). Two insular regions are differentially involved in behavioral variant FTD and nonfluent/agrammatic variant PPA. *Cortex*, *74*, 149-157. https://doi.org/10.1016/j.cortex.2015.10.012

Maratsos, M. P. (2014). How the acquisition of nouns may be different from that of verbs. In *Biological and behavioral determinants of language development* (pp. 67-88). Psychology Press.

Marczinski, C. A., & Kertesz, A. (2006). Category and letter fluency in semantic dementia, primary progressive aphasia, and Alzheimer's disease. *Brain and language*, *97*(3), 258-265. https://doi.org/10.1016/j.bandl.2005.11.001

Marini, A., Andreetta, S., Del Tin, S., & Carlomagno, S. (2011). A multi-level approach to the analysis of narrative language in aphasia. *Aphasiology*, *25*(11), 1372-1392. https://doi.org/10.1080/02687038.2011.584690

Mayer, J., & Murray, L. (2003). Functional measures of naming in aphasia: Word retrieval in confrontation naming versus connected speech. *Aphasiology*, *17*(5), 481-497. https://doi.org/10.1080/02687030344000148

McRae, K., Cree, G. S., Seidenberg, M. S., & McNorgan, C. (2005). Semantic feature production norms for a large set of living and nonliving things. *Behavior research methods*, *37*(4), 547-559. https://doi.org/10.3758/BF03192726

Medina, J., & Weintraub, S. (2007). Depression in primary progressive aphasia. *Journal of geriatric psychiatry and neurology*, *20*(3), 153-160. https://doi.org/10.1177/0891988707303603

Mesulam, M. M. (1982). Slowly progressive aphasia without generalized dementia. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, *11*(6), 592-598. https://doi.org/10.1002/ana.410110607

Mesulam, M. M., Grossman, M., Hillis, A., Kertesz, A., & Weintraub, S. (2003). The core and halo of primary progressive aphasia and semantic dementia. *Annals of Neurology: Official*

Journal of the American Neurological Association and the Child Neurology Society, *54*(S5), S11-S14. https://doi.org/10.1002/ana.10569

Mesulam, M. M., Rogalski, E. J., Wieneke, C., Hurley, R. S., Geula, C., Bigio, E. H., Thompson, C. K., & Weintraub, S. (2014). Primary progressive aphasia and the evolving neurology of the language network. *Nature Reviews Neurology*, *10*(10), 554-569. https://doi.org/10.1038/nrneurol.2014.159

Mesulam, M., Wicklund, A., Johnson, N., Rogalski, E., Léger, G. C., Rademaker, A., Weintraub, S., & Bigio, E. H. (2008). Alzheimer and frontotemporal pathology in subsets of primary progressive aphasia. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, *63*(6), 709-719. https://doi.org/10.1002/ana.21388

Middleton, E. L., & Schwartz, M. F. (2010). Density pervades: An analysis of phonological neighbourhood density effects in aphasic speakers with different types of naming impairment. *Cognitive neuropsychology*, *27*(5), 401-427. https://doi.org/10.1080/02643294.2011.570325

Minsky, M. (1975). A framework for representing knowledge. In P. H. Winston (Ed.), *The psychology of computer vision* (pp. 211-277). New York: McGraw-Hill. https://doi.org/10.1515/9783110858778

Miozzo, M., & Caramazza, A. (1997). Retrieval of lexical–syntactic features in tip-of-the tongue states. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(6), 1410. https://doi.org/10.1037/0278-7393.23.6.1410

Mirman, D. (2011). Effects of near and distant semantic neighbors on word production. *Cognitive, Affective, & Behavioral Neuroscience*, *11*, 32-43. https://doi.org/10.3758/s13415-010-0009-7

Mirman, D., & Magnuson, J. S. (2008). Attractor dynamics and semantic neighborhood density: processing is slowed by near neighbors and speeded by distant neighbors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(1), 65. https://doi.org/10.1037/0278-7393.34.1.65

Mirman, D., & Magnuson, J. S. (2009). Dynamics of activation of semantically similar concepts during spoken word recognition. *Memory & cognition*, *37*(7), 1026-1039. https://doi.org/10.3758/MC.37.7.1026

Mohammad, S. (2018). Obtaining reliable human ratings of valence, arousal, and dominance for 20,000 English words. *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, 174–184. https://doi.org/10.18653/v1/P18-1017

Montembeault, M., Brambati, S. M., Gorno-Tempini, M. L., & Migliaccio, R. (2018). Clinical, anatomical, and pathological features in the three variants of primary progressive aphasia: a review. *Frontiers in neurology*, *9*, 692. https://doi.org/10.3389/fneur.2018.00692

Morrison, C. M., & Ellis, A. W. (1995). Roles of word frequency and age of acquisition in word naming and lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(1), 116. https://doi.org/10.1037/0278-7393.21.1.116

Mummery, C. J., Patterson, K., Wise, R. J., Vandenbergh, R., Price, C. J., & Hodges, J. R. (1999). Disrupted temporal lobe connections in semantic dementia. *Brain*, *122*(1), 61-73. https://doi.org/10.1093/brain/122.1.61

Nakic, M., Smith, B. W., Busis, S., Vythilingam, M., & Blair, R. J. R. (2006). The impact of affect and frequency on lexical decision: the role of the amygdala and inferior frontal cortex. *Neuroimage*, *31*(4), 1752-1761. https://doi.org/10.1016/j.neuroimage.2006.02.022

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Neary, D., Snowden, J. S., Gustafson, L., Passant, U., Stuss, D., Black, S. A., Freedman, M., Kertesz, A., Robert, P. H., Albert, M., Boone, K., Miller, B. L., Cummings, J., & Benson, D. (1998). Frontotemporal lobar degeneration: a consensus on clinical diagnostic criteria. *Neurology*, *51*(6), 1546-1554. https://doi.org/10.1212/WNL.51.6.1546

Newton, C., Thornley, H., & Bruce, C. (2020). The influence of emotional valence on word recognition in people with aphasia. *Language, Cognition and Neuroscience*, *35*(8), 1064–1072. https://doi.org/10.1080/23273798.2020.1713385

Nicholas, L. E., & Brookshire, R. H. (1993). A system for scoring main concepts in the discourse of non-brain-damaged and aphasic speakers. In *Clinical Aphasiology Conference*, *21*, 87-99.

Nicholas, L. E., & Brookshire, R. H. (1995). Presence, completeness, and accuracy of main concepts in the connected speech of non-brain-damaged adults and adults with aphasia. *Journal of Speech, Language, and Hearing Research*, *38*(1), 145-156. https://doi.org/10.1044/jshr.3801.145

Nicholas, L. E., Brookshire, R. H., Maclennan, D. L., Schumacher, J. G., & Porrazzo, S. A. (1989). Revised administration and scoring procedures for the Boston Naming Test and norms for non-brain-damaged adults. *Aphasiology*, *3*(6), 569–580.

https://doi.org/10.1080/02687038908249023

Nickels, L. (1995). Getting it right? Using aphasic naming errors to evaluate theoretical models of spoken word recognition. Language and Cognitive Processes, 10(1), 13-45. https://doi.org/10.1080/01690969508407086

Nickels, L. (2002). Therapy for naming disorders: Revisiting, revising, and reviewing. *Aphasiology*, *16*(10-11), 935-979. https://doi.org/10.1080/02687030244000563

Nickels, L. (2014). *Spoken word production and its breakdown in aphasia*. Psychology Press. https://doi.org/10.4324/9781315804620

Nickels, L., & Howard, D. (1995). Aphasic naming: What matters?. *Neuropsychologia*, *33*(10), 1281-1303. https://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. https://doi.org/10.1080/02643290342000122

Oldfield, R. C., & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology*, *17*(4), 273-281. https://doi.org/10.1080/17470216508416445

Olness, G. S., & Ulatowska, H. K. (2011). Personal narratives in aphasia: Coherence in the context of use. *Aphasiology*, *25*(11), 1393-1413. https://doi.org/10.1080/02687038.2011.599365

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology/Revue canadienne de psychologie*, *45*(3), 255.

Peach, R. K., & Reuter, K. A. (2010). A discourse-based approach to semantic feature analysis for the treatment of aphasic word retrieval failures. *Aphasiology*, *24*(9), 971-990.

https://doi.org/10.1080/02687030903058629

Perret, C., & Bonin, P. (2019). Which variables should be controlled for to investigate picture naming in adults? A Bayesian meta-analysis. *Behavior Research Methods*, *51*(6), 2533–2545. https://doi.org/10.3758/s13428-018-1100-1

Perret, C., Schneider, L., Dayer, G., & Laganaro, M. (2014). Convergences and divergences between neurolinguistic and psycholinguistic data in the study of phonological and phonetic encoding: A parallel investigation of syllable frequency effects in brain-damaged and healthy speakers. *Language, Cognition and Neuroscience*, *29*(6), 714-727. https://doi.org/10.1080/01690965.2012.678368

Pinker, S. (2013). *Learnability and cognition, new edition: The acquisition of argument structure*. MIT press.

Pisoni, D. B., Nusbaum, H. C., Luce, P. A., & Slowiaczek, L. M. (1985). Speech perception, word recognition and the structure of the lexicon. *Speech Communication*, *4*(1–3), 75–95. https://doi.org/10.1016/0167-6393(85)90037-8

Pitt, M. A., & Samuel, A. G. (2006). Word length and lexical activation: longer is better. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(5), 1120. https://doi.org/10.1037/0096-1523.32.5.1120

Pulvermüller, F. (2005). Brain mechanisms linking language and action. *Nature reviews neuroscience*, *6*(7), 576-582. https://doi.org/10.1038/nrn1706

Rapcsak, S. Z., Beeson, P. M., Henry, M. L., Leyden, A., Kim, E., Rising, K., Andersen, S., & Cho, H. (2009). Phonological dyslexia and dysgraphia: Cognitive mechanisms and neural substrates. *Cortex*, *45*(5), 575-591. https://doi.org/10.1016/j.cortex.2008.04.006

Rapp, B., & Goldrick, M. (2000). Discreteness and interactivity in spoken word production. *Psychological review*, *107*(3), 460.https://doi.org/10.1037/0033-295X.107.3.460

Recio, G., Conrad, M., Hansen, L. B., & Jacobs, A. M. (2014). On pleasure and thrill: The interplay between arousal and valence during visual word recognition. *Brain and Language*, *134*, 34–43. https://doi.org/10.1016/j.bandl.2014.03.009

Reilly, M., & Desai, R. H. (2017). Effects of semantic neighborhood density in abstract and concrete words. *Cognition*, *169*, 46-53. https://doi.org/10.1016/j.cognition.2017.08.004

Richardson, J. D., & Dalton, S. G. (2016). Main concepts for three different discourse tasks in a large non-clinical sample. *Aphasiology*, *30*(1), 45-73. https://doi.org/10.1080/02687038.2015.1057891

Ringle, C. M., Wende, S., & Becker, J.-M. (2022). *SmartPLS 4. Oststeinbek: SmartPLS GmbH*.

Rofes, A., Beran, M., Jonkers, R., Geerlings, M. I., & Vonk, J. M. (2023). What drives task performance in animal fluency in individuals without dementia? The SMART-MR study. *Journal of Speech, Language, and Hearing Research*, *66*(9), 3473-3485. https://doi.org/10.1044/2023_JSLHR-22-00445

Rofes, A., De Aguiar, V., Ficek, B., Wendt, H., Webster, K., & Tsapkini, K. (2019). The role of word properties in performance on fluency tasks in people with primary progressive aphasia. *Journal of Alzheimer's Disease*, *68*(4), 1521-1534. https://doi.org/10.3233/JAD-180990

Rogalski, E., Cobia, D., Harrison, T. M., Wieneke, C., Thompson, C. K., Weintraub, S., & Mesulam, M. M. (2011). Anatomy of language impairments in primary progressive

aphasia. *Journal of neuroscience*, *31*(9), 3344-3350. https://doi.org/10.1523/JNEUROSCI.5544-10.2011

Rogalsky, C., LaCroix, A. N., Chen, K. H., Anderson, S. W., Damasio, H., Love, T., & Hickok, G. (2018). The neurobiology of agrammatic sentence comprehension: A lesion study. *Journal of cognitive neuroscience*, *30*(2), 234-255. https://doi.org/10.1162/jocn_a_01200

Rogers, T. T., & McClelland, J. L. (2004). *Semantic cognition: A parallel distributed processing approach*. MIT press.

Rosen, H. J., Gorno–Tempini, M. L., Goldman, W. P., Perry, R. J., Schuff, N., Weiner, M., Feiwell, R., Kramer, J. H., & Miller, B. L. (2002). Patterns of brain atrophy in frontotemporal dementia and semantic dementia. *Neurology*, *58*(2), 198-208. https://doi.org/10.1212/WNL.58.2.198

Ross, K. B., & Wertz, R. T. (1999). Comparison of impairment and disability measures for assessing severity of, and improvement in, aphasia. *Aphasiology*, *13*, 113–124. https://doi.org/10.1080/026870399402235

Ruggero, L., Croot, K., & Nickels, L. (2023). Quality of life ratings and Proxy Bias in Primary Progressive Aphasia: two sides to the story?. *American Journal of Alzheimer's Disease & Other Dementias*, *38*, 15333175231177668. https://doi.org/10.1177/15333175231177668

Ruggero, L., Nickels, L., & Croot, K. (2019). Quality of life in primary progressive aphasia: What do we know and what can we do next?. *Aphasiology*, *33*(5), 498-519. https://doi.org/10.1080/02687038.2019.1568135

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *Neuroimage*, *27*(1), 188-200. https://doi.org/10.1016/j.neuroimage.2005.04.012

Sadat, J., Martin, C. D., Costa, A., & Alario, F. X. (2014). Reconciling phonological neighborhood effects in speech production through single trial analysis. *Cognitive psychology*, *68*, 33-58. https://doi.org/10.1016/j.cogpsych.2013.10.001

Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. *Brain and language*, *37*(3), 440-479. https://doi.org/10.1016/0093-934X(89)90030-8

Sailor, K. M., Zimmerman, M. E., & Sanders, A. E. (2011). Differential impacts of age of acquisition on letter and semantic fluency in Alzheimer's disease patients and healthy older adults. *Quarterly Journal of Experimental Psychology*, *64*(12), 2383-2391. https://doi.org/10.1080/17470218.2011.596660

Sajjadi, S. A., Patterson, K., Tomek, M., & Nestor, P. J. (2012). Abnormalities of connected speech in the non-semantic variants of primary progressive aphasia. *Aphasiology*, *26*(10), 1219-1237. https://doi.org/10.1080/02687038.2012.710318

Sanguedolce, G., Brook, S., Gruia, D. C., Naylor, P. A., & Geranmayeh, F. (2024). When whisper listens to aphasia: Advancing robust post-stroke speech recognition. In *Proc. of Interspeech* (pp. 1995-1999).

Scheffel, L., Duffy, J. R., Strand, E. A., & Josephs, K. A. (2021). Word fluency test performance in primary progressive aphasia and primary progressive apraxia of speech. *American journal of speech-language pathology*, *30*(6), 2635-2642. https://doi.org/10.1044/2021_AJSLP-21-00058

Schnur, T. T., & Wang, S. (2024). Differences in connected speech outcomes across elicitation methods. *Aphasiology*, *38*(5), 816-837. https://doi.org/10.1080/02687038.2023.2239509

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. https://doi.org/10.1016/j.jml.2005.10.002

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. https://doi.org/10.1080/02643290342000519

Schwen Blackett, D., & Harnish, S. M. (2022). A scoping review on the effects of emotional stimuli on language processing in people with aphasia. *Journal of Speech, Language, and Hearing Research*, *65*(11), 4327-4345. https://doi.org/10.1044/2022_JSLHR-22-00104

Scott, G. G., Keitel, A., Becirspahic, M., Yao, B., & Sereno, S. C. (2019). The Glasgow Norms: Ratings of 5,500 words on nine scales. *Behavior research methods*, *51*, 1258-1270. https://doi.org/10.3758/s13428-018-1099-3

Seixas-Lima, B., Murphy, K., Troyer, A. K., Levine, B., Graham, N. L., Leonard, C., & Rochon, E. (2020). Episodic memory decline is associated with deficits in coherence of discourse. *Cognitive Neuropsychology*, *37*(7-8), 511-522. https://doi.org/10.1080/02643294.2020.1770207

Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in psychology*, *5*, 772. https://doi.org/10.3389/fpsyg.2014.00772

Shaoul, C., & Westbury, C. (2010). Exploring lexical co-occurrence space using HiDEx. *Behavior Research Methods*, *42*(2), 393–413. https://doi.org/10.3758/BRM.42.2.393

Snowden, J. S., Griffiths, H. L., & Neary, D. (1996). Semantic-episodic memory interactions in semantic dementia: Implications for retrograde memory function. *Cognitive*

Neuropsychology, *13*(8), 1101–1139. https://doi.org/10.1080/026432996381674

Snowden, J. S., Harris, J. M., Thompson, J. C., Kobylecki, C., Jones, M., Richardson, A. M., & Neary, D. (2018). Semantic dementia and the left and right temporal lobes. *Cortex*, *107*, 188-203. https://doi.org/10.1016/j.cortex.2017.08.024

Stark, B. C. (2019). A comparison of three discourse elicitation methods in aphasia and age-matched adults: Implications for language assessment and outcome. *American Journal of Speech-Language Pathology*, *28*(3), 1067-1083. https://doi.org/10.1044/2019_AJSLP-18-0265

Stemberger, J. P. (2004). Neighbourhood effects on error rates in speech production. *Brain and Language*, *90*(1-3), 413-422. https://doi.org/10.1016/S0093-934X(03)00452-8

Steyvers, M., & Tenenbaum, J. B. (2005). The large-scale structure of semantic networks: Statistical analyses and a model of semantic growth. *Cognitive science*, *29*(1), 41-78. https://doi.org/10.1207/s15516709cog2901_3

Strain, E., & Herdman, C. M. (1999). Imageability effects in word naming: an individual differences analysis. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *53*(4), 347. https://doi.org/10.1037/h0087322

Thompson, C. K. (2012). Northwestern assessment of verbs and sentences (NAVS).

Thompson, C. K., & Mack, J. E. (2014). Grammatical impairments in PPA. *Aphasiology*, *28*(8-9), 1018-1037. https://doi.org/10.1080/02687038.2014.912744

Thompson, C. K., Meltzer-Asscher, A., Cho, S., Lee, J., Wieneke, C., Weintraub, S., & Mesulam, M. M. (2013). Syntactic and morphosyntactic processing in stroke-induced and primary progressive aphasia. *Behavioural neurology*, *26*(1-2), 35-54. https://doi.org/10.3233/BEN-2012-110220

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. *Neuropsychology*, *11*(1), 138. https://doi.org/10.1037/0894-4105.11.1.138

Tsai, J. L., Knutson, B., & Fung, H. H. (2006). Cultural variation in affect valuation. *Journal of Personality and Social Psychology*, *90*(2), 288. https://doi.org/10.1037/0022-3514.90.2.288

Ukita, H., Abe, K., & Yamada, J. (1999). Late acquired words in childhood are lost earlier in primary progressive aphasia. *Brain and Language*, *70*(2), 205–219. https://doi.org/10.1006/brln.1999.2152

Ulatowska, H. K., Allard, L., & Chapman, S. B. (1990). Narrative and procedural discourse in aphasia. In *Discourse ability and brain damage: Theoretical and empirical perspectives* (pp. 180-198). New York, NY: Springer New York. https://doi.org/10.1007/978-1-4612-3262-9_8

van den Berg, E., Dijkzeul, J. C. M., Poos, J. M., Eikelboom, W. S., van Hemmen, J., Franzen, S., de Jong, F. J., Dopper, E. G. P., Vonk, J. M. J., Papma, J. M., Satoer, D., Jiskoot, L. C., & Seelaar, H. (2024). Differential linguistic features of verbal fluency in behavioral variant frontotemporal dementia and primary progressive aphasia. *Applied Neuropsychology: Adult*, *31*(4), 669-677. https://doi.org/10.1080/23279095.2022.2060748

Vigliocco, G., Vinson, D. P., Druks, J., Barber, H., & Cappa, S. F. (2011). Nouns and verbs in the brain: A review of behavioural, electrophysiological, neuropsychological and imaging studies. *Neuroscience & Biobehavioral Reviews*, *35*(3), 407-426. https://doi.org/10.1016/j.neubiorev.2010.04.007

Vitevitch, M. S. (2002). The influence of phonological similarity neighborhoods on speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(4), 735. https://doi.org/10.1037/0278-7393.28.4.735

Vitevitch, M. S., & Luce, P. A. (1999). Probabilistic phonotactics and neighborhood activation in spoken word recognition. *Journal of memory and language*, *40*(3), 374-408. https://doi.org/10.1006/jmla.1998.2618

Vitevitch, M. S., & Luce, P. A. (2005). Increases in phonotactic probability facilitate spoken nonword repetition. *Journal of memory and language*, *52*(2), 193-204. https://doi.org/10.1016/j.jml.2004.10.003

Vitevitch, M. S., & Luce, P. A. (2016). Phonological neighborhood effects in spoken word perception and production. *Annual Review of Linguistics*, *2*, 75–94. https://doi.org/10.1146/annurev-linguistics-030514-124832

Vitevitch, M. S., Luce, P. A., Pisoni, D. B., & Auer, E. T. (1999). Phonotactics, neighborhood activation, and lexical access for spoken words. *Brain and language*, *68*(1-2), 306-311. https://doi.org/10.1006/brln.1999.2116

Vitevitch, M. S., Stamer, M. K., & Sereno, J. A. (2008). Word length and lexical competition: Longer is the same as shorter. *Language and Speech*, *51*(4), 361–383. https://doi.org/10.1177/0023830908099070

Vonk, J. M., Rizvi, B., Lao, P. J., Budge, M., Manly, J. J., Mayeux, R., & Brickman, A. M. (2019). Letter and category fluency performance correlates with distinct patterns of cortical thickness in older adults. *Cerebral Cortex*, *29*(6), 2694-2700. https://doi.org/10.1093/cercor/bhy138

Warrington, E. K. (1984). *Recognition memory test*. Western Psychological Services.

Watson, C. L., Possin, K., Allen, I. E., Hubbard, H. I., Meyer, M., Welch, A. E., Rabinovici, G.

D., Rosen, H., Rankin, K. P., Miller, Z., Santos-Santos, M. A., Kramer, J. H., Miller, B. L., & Gorno-Tempini, M. L. (2018). Visuospatial functioning in the primary progressive aphasias. *Journal of the International Neuropsychological Society*, *24*(3), 259-268. https://doi.org/10.1017/S1355617717000984

Wechsler, D. (2008). Wechsler adult intelligence scale–Fourth Edition (WAIS–IV). *San Antonio, TX: NCS Pearson*, *22*(498), 816–827.

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *Journal of Cognitive Neuroscience*, *12*(6), 1024-1037. https://doi.org/10.1162/08989290051137558

Westbury, C. F., Shaoul, C., Hollis, G., Smithson, L., Briesemeister, B. B., Hofmann, M. J., & Jacobs, A. M. (2013). Now you see it, now you don't: on emotion, context, and the algorithmic prediction of human imageability judgments. *Frontiers in psychology*, *4*, 991. https://doi.org/10.3389/fpsyg.2013.00991

Wilson, S. M., Henry, M. L., Besbris, M., Ogar, J. M., Dronkers, N. F., Jarrold, W., Miller, B. L., & Gorno-Tempini, M. L. (2010). Connected speech production in three variants of primary progressive aphasia. *Brain*, *133*(7), 2069-2088. https://doi.org/10.1093/brain/awq129

Wilson, S. M., Isenberg, A. L., & Hickok, G. (2009). Neural correlates of word production stages delineated by parametric modulation of psycholinguistic variables. *Human Brain Mapping*, *30*(11), 3596–3608. https://doi.org/10.1002/hbm.20782

Wright, H. H., & Capilouto, G. J. (2009). Manipulating task instructions to change narrative discourse performance. *Aphasiology*, *23*(10), 1295-1308. https://doi.org/10.1080/02687030902826844

Wu, C., Shi, Y., & Zhang, J. (2023). Beyond valence and arousal: the role of age of acquisition in emotion word recognition. *Behavioral Sciences*, *13*(7), 568. https://doi.org/10.3390/bs13070568

Yang, J., Zeng, J., Meng, X., Zhu, L., Yuan, J., Li, H., & Yusoff, N. (2013). Positive words or negative words: Whose valence strength are we more sensitive to?. *Brain research*, *1533*, 91-104. https://doi.org/10.1016/j.brainres.2013.08.020

Zimmerer, V. C., Hardy, C. J., Eastman, J., Dutta, S., Varnet, L., Bond, R. L., Russell, L., Rohrer, J. D., Warren, J. D., & Varley, R. A. (2020). Automated profiling of spontaneous speech in primary progressive aphasia and behavioral-variant frontotemporal dementia: An approach based on usage-frequency. *Cortex*, *133*, 103-119. https://doi.org/10.1016/j.cortex.2020.08.027