



## What do pauses in narrative production reveal about the nature of word retrieval deficits in PPA?



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### ABSTRACT

Naming and word-retrieval deficits, which are common characteristics of primary progressive aphasia (PPA), differentially affect production across word classes (e.g., nouns, verbs) in some patients. Individuals with the agrammatic variant (PPA-G) often show greater difficulty producing verbs whereas those with the semantic variant (PPA-S) show greater noun deficits and those with logopenic PPA (PPA-L) evince no clear-cut differences in production of the two word classes. To determine the source of these production patterns, the present study examined word-finding pauses as conditioned by lexical variables (i.e., word class, frequency, length) in narrative speech samples of individuals with PPA-S ( $n=12$ ), PPA-G ( $n=12$ ), PPA-L ( $n=11$ ), and cognitively healthy controls ( $n=12$ ). We also examined the relation between pause distribution and cortical atrophy (i.e., cortical thickness) in nine left hemisphere regions of interest (ROIs) linked to word production. Results showed higher overall pause rates for PPA compared to unimpaired controls; however, greater naming severity was not associated with increased pause rate. Across all groups, more pauses were produced before lower vs. higher frequency words, with no independent effects of word length after controlling for frequency. With regard to word class, the PPA-L group showed a higher rate of pauses prior to production of nouns compared to verbs, consistent with noun-retrieval deficits arising at the lemma level of word production. Those with PPA-G and PPA-S, like controls, produced similar pause rates across word classes; however, lexical simplification (i.e., production of higher-frequency and/or shorter words) was evident in the more-impaired word class: nouns for PPA-S and verbs for PPA-G. These patterns are consistent with conceptual and/or lemma-level impairments for PPA-S, predominantly affecting objects/nouns, and a lemma-level verb-retrieval deficit for PPA-G, with a concomitant impairment in phonological encoding and articulation affecting overall pause rates. The greater tendency to pause before nouns was correlated with atrophy in the left precentral gyrus, inferior frontal gyrus and inferior parietal lobule, whereas the greater tendency to pause before less frequent and longer words was associated with atrophy in left precentral and inferior parietal regions.

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### 1. Introduction

Naming and word-finding deficits are commonly seen in patients with primary progressive aphasia (PPA), even though the nature of these and other deficits differs across PPA variants.

Models of word production address multiple stages of naming, including conceptual preparation, lemma retrieval (i.e., access and selection of an abstract lexical unit specified for semantic and syntactic information), retrieval of the phonological word-form, phonological encoding (i.e., syllabification and segmentation), and motor speech planning and articulation (Caramazza, 1997; Dell and O'Seaghdha, 1992; Levelt et al., 1999; Roelofs, 1992). Accordingly, naming impairments in PPA may reflect breakdown at one or more of these stages. For example, the semantic variant of PPA

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(PPA-S) has been linked to difficulty at the conceptual and/or lemma levels. Noun naming is more impaired than verb naming in PPA-S, stemming from impaired lexical–semantic representations (e.g., a blurring of semantic distinctions within taxonomic categories) as well as impaired mapping from the semantic features of objects to the retrieval of noun lemmas (Hillis et al., 2006, 2004; Hurley et al., 2012; Mesulam et al., 2009a, 2013; Thompson et al., 2012a, 2012c; Wilson et al., 2010). Noun naming deficits lead to semantically impoverished language, with production of primarily high-frequency, abstract, and/or vague words (Bird et al., 2000; Hoffman et al., 2014; Meteyard and Patterson, 2009; Wilson et al., 2010).

The source of naming deficits in the logopenic (PPA-L) and agrammatic (PPA-G) variants is less clear. Both subtypes have been associated with impairments at the phonological level, with some studies pointing to impaired phonological word-form retrieval in PPA-L and deficits in phonological encoding, as well as motor speech planning and articulation, in PPA-G (Ash et al., 2010; Ballard et al., 2014; Hurley et al., 2012; Mack et al., 2013a; Mesulam et al., 2012; Wilson et al., 2010). However, studies of online word production, showing abnormal semantic interference effects in individuals with PPA-L and PPA-G, suggest possible lemma-level deficits as well (Thompson et al., 2012b). In PPA-G, verbs are more impaired than nouns and these effects are more pronounced in confrontation naming (Hillis et al., 2006, 2004; Thompson et al., 2012c) than in narrative speech, although noun to verb (N:V) ratios are numerically (but not significantly) elevated compared to controls (Thompson et al., 2012a; Wilson et al., 2010). In addition, individuals with PPA-G exhibit more difficulty retrieving verbs with complex (two-argument) vs. simple (one-argument) lemmas, despite intact comprehension of both verb types (Thompson et al., 2012c), suggesting that verb production deficits may arise at the lemma level. Differences in verb production between naming and narrative tasks have not yet been explained. One possibility is that verb deficits in narratives are manifest in part through lexical simplification, e.g., selection of higher-frequency and/or phonologically less complex word forms to lessen retrieval demands, which may reduce the degree of impairment as measured by overall word class production patterns (i.e., N:V ratios).

In PPA-L, word class effects have not been found in naming (Thompson et al., 2012c), but trends towards impaired noun production have been noted in narrative speech (Thompson et al., 2012a; Wilson et al., 2010). One possible reason for this is that PPA-L may be associated with lemma-level noun retrieval deficits that emerge due to the demands of narrative speech, i.e., tracking a set of referents (e.g., *Cinderella*, *prince*, *fairy godmother*, *glass slipper*) and repeatedly selecting from this set throughout the construction of the narrative. Alternatively, trends towards reduced noun production in narrative speech may result from impaired phonological word-form retrieval (Mack et al., 2013a). Even in unimpaired speakers, nouns tend to be longer and of lower frequency than verbs in Cinderella story narratives (Bird and Franklin, 1996; MacWhinney et al., 2010). Because word length and frequency may affect the ease of phonological word-form retrieval (Garrett, 1982; Jescheniak and Levelt, 1994; Wilson et al., 2009), these variables may particularly affect noun production in PPA-L.

One variable in spoken language that reflects word retrieval processes is the distribution of pauses. In unimpaired individuals, pauses have been shown to reflect word production difficulty both at the level of lemma access and selection (pauses tend to be produced before less semantically-predictable words; Beattie and Butterworth, 1979; Goldman-Eisler, 1958; Griffin and Bock, 1998) and at the level of phonological word-form retrieval and encoding (pauses tend to occur before less-frequent words; Beattie and Butterworth, 1979; Griffin and Bock, 1998; Jescheniak and Levelt,

1994). Similarly, aphasic individuals may produce pauses due to processing difficulty either at the lemma or phonological level (Garrett, 1982). In addition, pauses may result from deficits in motor speech planning and articulatory processes (Ballard et al., 2014; Duffy, 2006). Thus, the distribution of pauses can potentially inform accounts of word retrieval deficits in PPA across multiple levels of representation.

Pauses also are of interest due to their putative prevalence in PPA-L. Indeed, Mesulam and Weintraub (1992) initially defined “logopenic” speech as a paucity of output due to long word-finding pauses (p. 587), and more recently, we (Mesulam et al., 2012, p. 1550) noted that word-finding pauses are the “most conspicuous clinical feature” of PPA-L, given that grammar and word comprehension are generally intact in this subtype. Consistent with this observation, previous studies have found a high rate of pauses in PPA-L (Ash et al., 2013; Teichmann et al., 2013; Wilson et al., 2010). However, PPA-G has also been associated with abnormally frequent and/or long pauses (Ballard et al., 2014; Ash et al., 2013; Rohrer et al., 2010; Wilson et al., 2010). This raises the question of whether the distribution of pauses differs between the two subtypes, potentially reflecting distinct language processing impairments.

The present study examined the distribution of pauses across nouns and verbs produced in the narrative speech of individuals with PPA and age-matched cognitively healthy control speakers. Word class effects on pause distribution may reflect lemma-level retrieval deficits, whereas word frequency effects may relate to impaired phonological word-form retrieval (Jescheniak and Levelt, 1994) and word length effects may reflect impaired phonological word-form retrieval or subsequent phonological encoding and articulatory processes (Wilson et al., 2009), neither of which would affect production by word class. On the hypothesis that noun-retrieval deficits in PPA-S emerge at the lemma and/or conceptual levels (Hurley et al., 2012; Mesulam et al., 2009a, 2013), we predicted that individuals with PPA-S would pause more frequently before nouns compared to verbs. In contrast, given that verb production is more impaired than noun production in PPA-G (Thompson et al., 2012c), we expected more frequent pausing before verbs, reflecting lemma level impairment. However, if impaired phonological encoding and articulatory processes also are impaired in PPA-G (Ash et al., 2010; Mack et al., 2013a; Ballard et al., 2014), high pause rates overall, influencing both noun and verb production, were expected. For PPA-L, we tested two possible accounts: that word-retrieval impairments (1) are lemma-based (cf. Hurley et al., 2012; Thompson et al., 2012b) and would, therefore, result in increased pausing before nouns, and/or (2) result from impaired phonological word-form retrieval (Mack et al., 2013a), in which case increased pausing before low-frequency and longer words, with no independent effects of word class, was predicted.

The present study also aimed to identify the neural correlates of pauses in PPA. Only three studies, to our knowledge, have investigated this relationship, finding atrophy in the left superior temporal gyrus (STG) (Ash et al., 2013; Wilson et al., 2010), the inferior parietal region (Ash et al., 2013), and/or frontal regions (Ballard et al., 2014). Differences across studies may relate to pause coding procedures and the specific pause measures chosen (e.g., filled pauses vs. unfilled pauses, pause rate vs. pause duration, etc.). In addition, the neural substrates of pauses may differ depending on their source (e.g., lemma retrieval vs. phonological word-form retrieval vs. phonological encoding and articulation), which has not been addressed in previous studies. We examined cortical atrophy in nine left hemisphere ROIs that have been linked to fluency and word production in healthy individuals as well as those with stroke aphasia and PPA: the pars opercularis, pars triangularis, and pars orbitalis of the inferior frontal gyrus (IFG), the

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