Quantitative rate measures as a function of severity across three subtypes of primary progressive aphasia

Introduction:

Primary progressive aphasia (PPA) is a neurodegenerative aphasic syndrome that can be classified into three main subtypes: agrammatic/non-fluent (nfvPPA), logopenic (lvPPA), and semantic (svPPA). Non-fluent or apraxic speech—typified by slow speech and/or speech sound errors—is a core feature of nfvPPA (Gorno-Tempini et al., 2011). Prior research suggests the potential for a speech rate measure to be a reliable indicator of non-fluent speech in PPA, which could help differentiate nfvPPA from lvPPA and svPPA (Wilson et al., 2010). The use of speech rate as a metric for speech non-fluency has several advantages, the most important being that it is decomposable into subcomponent measures of articulation rate (i.e., a measure of speaking rate excluding pause time) and proportion pause time, which represent motor and cognitive/linguistic contributions to speech, respectively.

Emerging evidence suggests that subcomponent measures of speech rate, particularly articulation rate, may be better at differentiating PPA subtypes than speech rate alone (Cordella et al., 2017; Wilson et al., 2010). This is especially true for the differentiation between nfvPPA and lvPPA, a clinically difficult distinction to make because lvPPA individuals present with variable non-fluency due to word-finding problems (Gorno-Tempini et al., 2008; Mack et al., 2015). Thus, subcomponent measures of speech rate provide a means to distinguish lvPPA individuals—whose speech rate may be slowed due to increased pausing associated with word-finding difficulties, and nfvPPA individuals—whose speech rate may be slowed due to reduced speed of articulator movement secondary to a motor speech impairment.

Although subcomponent measures of speech rate have been shown to be effective at differentiating PPA subtypes overall, very little research has looked specifically at the effectiveness of these measures at differentiating subtypes across different severity levels. An objective measure that separates subtypes in the mild stages of impairment stands to aid differential subtype diagnosis and could inform early management of speech symptoms. Research is, therefore, needed to determine the effectiveness of subcomponent measures of speech rate at differentiating subtypes in mild stages of impairment and to investigate how these rate measures change in each of the three subgroups as patients progress to more severe stages of impairment.

Aims:

The aims of the current study were two-fold. First, we evaluated if speech rate and its subcomponent measures—including articulation rate and proportion pause—effectively differentiated PPA subtypes during both mild and moderate/severe stages of impairment. Second, we analyzed subtype-specific trajectories of decline for each of the quantitative rate measures to compare differential patterns of decline across groups ranging from mild to moderate to severe levels of impairment.

Method:

Participant characteristics

Participants included 60 individuals with a diagnosis of PPA (20 nfvPPA, 22 lvPPA, 18 svPPA) recruited through the Massachusetts General Hospital Frontotemporal Disorders Unit PPA Program and 8 healthy age-matched controls. For each PPA participant, severity was indexed using a subset of ratings from the Progressive Aphasia Severity Scale (PASS; Sapolsky et al., 2010), an instrument used to rate degree of impairment (0-3 interval scale; Table 1) across ten primary speech and language domains; seven domains were selected for measurement of severity in this study. PASS ratings were used to determine overall severity per individual (i.e., average score across all seven PASS domains) and subtype-specific severity, calculated as the average score per individual across domains canonically

associated with his/her subtype diagnosis (Table 2). An individual's subtype-specific severity score was then used to group patients into mild (subtype severity ≤.5**)**, moderate (<1), and severe (≥1) groups.

Speech/pause data analysis

All 68 participants responded to the picture description task of the Western Aphasia Battery (Kertesz, 1982). Audio was processed using a MATLAB-based program, Speech Pause Analysis (SPA), which algorithmically estimates speech and pause segments in continuous speech (Green, Beukelman, & Ball, 2004). Syllable counts and automatic SPA output were combined to derive the following experimental variables: speech rate, articulation rate, and proportion pause time (Table 3).

A series of one-factor ANOVAs were conducted for each of the quantitative fluency variables in order to detect significant differences between groups (nfvPPA, lvPPA, svPPA and normal controls) within each severity level (mild, moderate/severe). Post-hoc tests conducted as appropriate. For this between-groups analysis, severity was collapsed to include two groups: mild and moderate/severe. Patient characteristics of each of these two severity groups are given in Tables 4 and 5. ANOVAs were also conducted for each of the quantitative variables to detect significant differences within subtype groups across different severity stages; for this analysis, the three-way severity distinction (mild, moderate, severe) was maintained.

Results:

As listed in Table 6, there were statistically significant main effects across groups for speech and articulation rate in the mild severity stage. The nfvPPA group had significantly reduced speech rate compared to lvPPA and normal control groups. Articulation rate was the most effective measure for differentiating between nfvPPA and the lvPPA, svPPA, and normal control groups in the mild stages of impairment. In the moderate/severe stages of impairment, all three quantitative rate measures differentiated groups (See Table 7). Proportion pause differentiated nfvPPA from svPPA and normal controls, with the latter two groups pausing significantly less. Speech and articulation rate successfully differentiated nfvPPA from not only svPPA and normal controls but also from lvPPA: nfvPPA individuals had significantly slower rates of speech and articulation as compared to lvPPA individuals in the moderate/severe stage.

In terms of within-groups trends across severity stages, results showed a decline for the nfvPPA group in speech rate (Figure 1) and articulation rate (Figure 2) moving from the mild to moderate stage. Both of these rate variables showed no significant change from the moderate to severe stage and proportion pause (Figure 3) showed only an increasing trend from the moderate to severe stage for the nfvPPA group. Several non-statistically significant trends were also noted, including: (1) decreases in speech and articulation rate in the lvPPA group as severity increased, and a corresponding increase in proportion pause time, and (2) increases in speech rate with severity in the svPPA group, and a corresponding decrease in proportion pause; no trend was discernible for articulation rate in this group.

Discussion:

Consistent with previous research, our results demonstrated the diagnostic value of subcomponent measures of speech rate for differentiating PPA subtypes, and suggest specifically that articulation rate is an efficacious marker for differential diagnosis of PPA subtypes even during the mild stages of impairment. The diagnostic utility of rate measures is reinforced by the finding that between-groups differences on these measures are maintained into moderate/severe stages.

Within-groups analyses of rate measures across different severity stages revealed divergent, subgroup-specific trends in these measures as a function of severity. The nfvPPA and lvPPA trajectories dissociated from that of svPPA: the former groups showed decreasing rates of speech as severity increased whereas the latter group showed a trend toward increasing speech rate in the later stages of

disease. The nfvPPA group further dissociated from lvPPA, as nfvPPA was characterized by a unique early drop in articulation rate from the mild to moderate severity stages. This trajectory of decline has important implications for early management of speech symptoms in nfvPPA. Depending on the degree to which slowed speech impedes functional communication for this group, findings could suggest the need for earlier introduction of alternative/augmentative communication methods for this group of patients.

References:

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Table 1. PASS rating scale

PASS Rating	Description of Impairment
0	Normal/no impairment
.5	Questionable/very mild
1	Mild
2	Moderate
3	Severe

Table 2. Subtype-specific severity using the PASS rating scale

Subtype	PASS Domains						
nfvPPA	Articulation	Fluency	Syntax	Word Retrieval	Repetition	Auditory Comprehension	Single Word Comprehension
lvPPA	Articulation	Fluency	Syntax	Word Retrieval	Repetition	Auditory Comprehension	Single Word Comprehension
svPPA	Articulation	Fluency	Syntax	Word Retrieval	Repetition	Auditory Comprehension	Single Word Comprehension

Table 3. Quantitative fluency measures

Variable Name	Derivation
Speech rate	= # total syllables / total response duration (s)
Articulation rate	= # total syllables / total speech duration (s)
Proportion pause	= total pause duration (s) / total response duration (s)

Table 4. Characteristics of patients in ***mild*** stages of impairment

	PPA			Omnibus significance
	nfvPPA (n=12)	***lvPPA (n=8)***	***svPPA (n=10)***	
Age (yrs)	66.32 ±7.69	71.67±4.27	68.68 ±7.23	ns
Sex (M/F)	4/8[b]	7/1[a]	4/6	.043
Overall Severity (PASS avg.)	.37 ±.09[c]	.31 ±.04	.23 ±.10[a]	.002
Subtype Specific Severity	.47±.06	.45±.06	.38±.13	ns

Superscript letters denote post-hoc significance relative to the [a]nfvPPA [b]lvPPA and [c]svPPA at p<0.05.

Table 5. Characteristics of patients in ***moderate/severe*** stages of impairment

	PPA			Omnibus significance
	nfvPPA (n=7)*	***lvPPA (n=14)***	***svPPA(n=8)***	
Age (yrs)	72.67 ±11.67	68.61 ±7.99	65.20 ±9.00	ns
Sex (M/F)	5/4	8/6	2/6	ns
Overall Severity (PASS avg.)	.76 ±.30	.63 ±.19	.52±.16	ns
Subtype Specific Severity	1.26±.52	.91±.25	.91±.27	ns

*Single nfvPPA participant excluded from moderate/severe group in order to equalize between-groups severity

Table 6. Mean, standard deviation and significance for quantitative fluency measures in ***mild*** stages of impairment

	p-value	nfvPPA (n=12)	lvPPA (n=8)	svPPA (n=10)	NC (n=8)
Speech rate (syll/s)	<.001	1.41±.40[b,d]	2.24±.85[a]	2.11±.69	2.88±.50[a]
Articulation rate (syll/s)	<.001	3.32 ±.65[b,c,d]	4.44 ±.82[a]	4.36 ±.71[a]	4.78±.32[a]
Proportion pause	.007	.57 ±.09[d]	.51 ±.10	.52 ±.13	.40 ±.09[a]

NC = Normal controls. p-value refers to overall between-groups significance per variable. Superscript letters denote post-hoc significance relative to the [a]nfvPPA [b]lvPPA [c]svPPA and [d]NC at p<0.05.

Table 7. Mean, standard deviation and significance for quantitative fluency measures in ***moderate/severe*** stages of impairment

	p-value	nfvPPA (n=7)	lvPPA (n=14)	svPPA (n=8)	NC (n=8)
Speech rate (syll/s)	<.001	.75±.30[b,c,d]	1.57 ±.64[a,c,d]	2.67±.53[a,b]	2.88 ±.5[a,b]
Articulation rate (syll/s)	<.001	1.96 ±.18[b,c,d]	3.70 ±.76[a,c,d]	4.64 ±.39[a,b]	4.78±.32[a,b]
Proportion pause	<.001	.62 ±.14[c,d]	.59 ±.12[c,d]	.42 ±.12[a,b]	.40 ±.09[a,b]

NC = Normal controls. p-value refers to overall between-groups significance per variable. Superscript letters denote post-hoc significance relative to the [a]nfvPPA [b]lvPPA [c]svPPA and [d]NC at p<0.05.

Figure 1. Speech rate as a function of subtype-specific severity across PPA subtypes

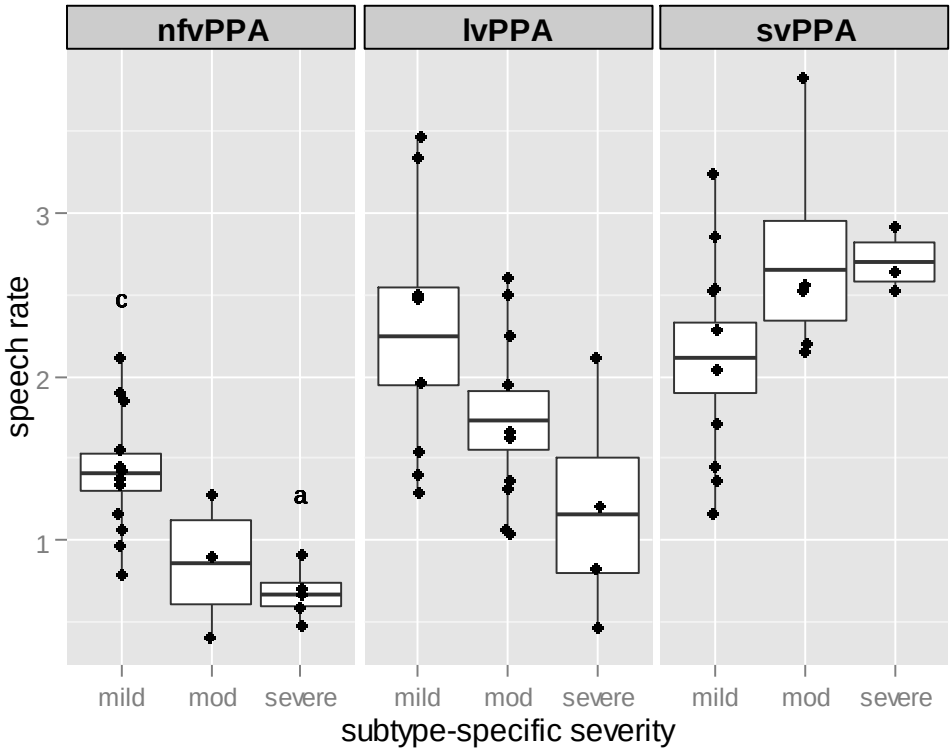

Figure 2. Articulation rate as a function of subtype-specific severity across PPA subtypes

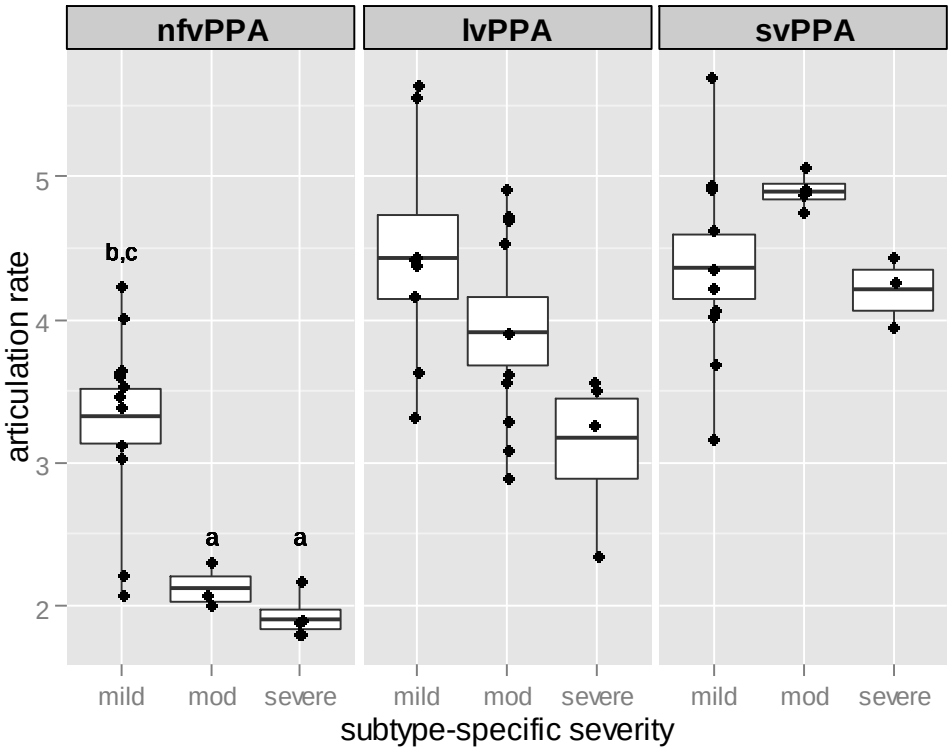

Figure 3. Proportion pause as a function of subtype-specific severity across PPA subtypes