Speech motor planning: Evidence from neurodegenerative disorder

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Introduction

- ❖ **Speech motor planning**: critical in speech production; take place after phonological/phonetic encoding and before speech motor execution.
- ❖ **Apraxia of speech (AOS)** is a disorder that affects speech motor planning ➔ distorted speech sounds, substitutions, insertions, inconsistent errors, groping behaviors, and deviations in tone, stress, or rhythm.
- ❖ AOS: typically co-occurs with aphasia (higher-level language disorder) and dysarthria (motor execution disorder).

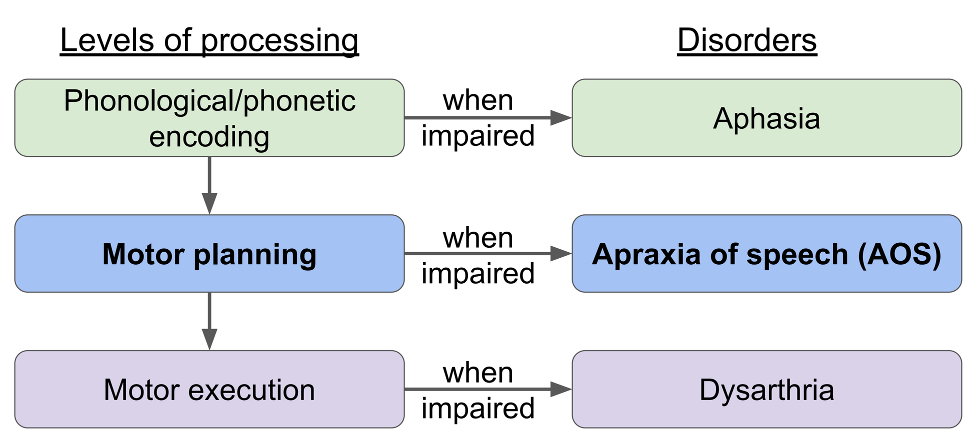

Figure 1. Processes and relevant disorders in speech production.

- ❖ However, there is **no consensus in the neural substrates** underlying speech motor planning.
  - ➢ Post-stroke AOS: associated with lesions to left precentral gyrus (PrCG) (Basilakos et al, 2015, 2018; Takakura et al., 2019).
  - ➢ Neurodegenerative disease: left premotor cortex and supplemental motor cortex (Utianski et al., 2018; Cordella et al., 2019).
- ❖ The specific **processes** involved in speech motor planning are often **underspecified**.
- ❖ This study: investigated AOS in individuals with Primary Progressive Aphasia (PPA, a neurodegenerative disorder affecting language), a less studied population.
  - ➢ Address issues specifically concerning the PPA phenotypes, evaluate if more diffuse damage profiles can provide additional insights into the nature of the speech planning processes

Research questions:
1. Which brain areas are uniquely associated with AOS in PPA?
2. What do the areas associated with AOS reveal about the specific processes that are impaired?

Methods

Participants: 34 PPA individuals (19 females; 12 lvPPA, 12 nfvPPA, 7 svPPA, 1 mixed, 2 unclassifiable)
Data:

Variable Mean (SD)	lvPPA (n = 12)	nfvPPA (n = 12)	svPPA (n = 7)
Age	66.75 (9.47)	67.58 (5.28)	65.14 (9.21)
Years of education	16.17 (2.89)	16.50 (2.43)	16.67 (1.03)
Years post onset	3.67 (2.45)	2.71 (1.64)	4.86 (3.13)
FTD-CDR	6.29 (3.17)	4.13 (3.16)	5.25 (3.08)

Table 1. Demographics of PPA participants.

- ❖ Behavioral data
  - ➢ **Oral picture naming**: Boston Naming Test (BNT; Williams et al., 1989)
  - ➢ **Single word repetition**: subtest 2 of Apraxia Battery for Adults (ABA2) (Dabul, 2000)
    - ■ 20 triplets of words, such as "thick, thicken, thickening"
    - ■ Length effect scores (difference in total item scores between the longest and shortest words in each triplet)
- ❖ Speech language pathologist (SLP) ratings: for **expressive aphasia**, **AOS**, and **dysarthria**
  - ➢ Based on audio recordings of BNT, ABA2, and picture description
  - ➢ Using an in-house scale of 0-3 (0 = absent, 3 = severe)
- ❖ Neuroimaging: T1-weighted MPRAGE structural scans

Analysis 1: Neural underpinnings of speech and language disorders
- ❖ Whole-brain voxel-based morphometry (VBM) on the T1-weighted images using FSL-VBM (Douaud et al., 2007) ➔ identify voxels significantly correlated ($p < .05$) with each SLP ratings, controlling for the other two ratings
  - ➢ Correction for multiple comparison: permutation-based non-parametric testing using threshold-free cluster enhancement (TFCE)

Analysis 2: Relationship between volume of significant clusters and SLP ratings
- ❖ Multiple regression analysis ➔ test if each cluster of significant voxels accounted for unique variance in SLP ratings
  - ➢ SLP ratings ~ cluster 1 volume + cluster 2 volume + …

Analysis 3: Brain areas associated with length effect
- ❖ Multiple regression analysis ➔ evaluate if length effects were uniquely associated with specific brain areas
  - ➢ length effect ~ cluster 1 volume + cluster 2 volume + …

Results

Analysis 1: Neural underpinnings of speech and language disorders

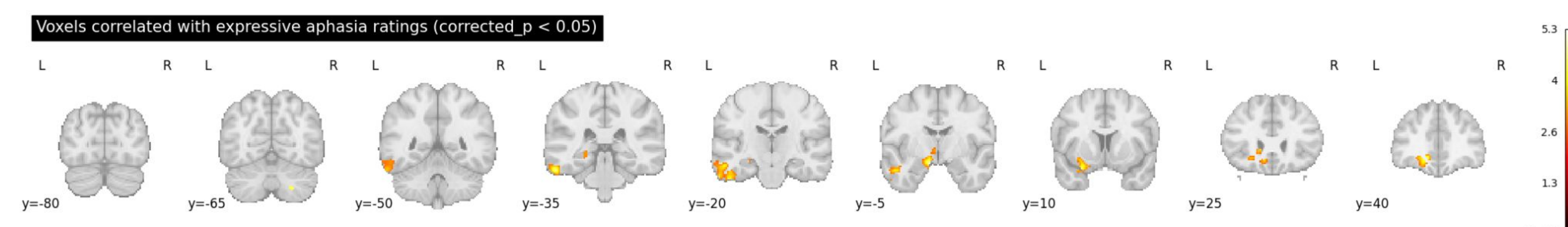

Figure 2. VBM results: Voxels significantly associated with expressive aphasia ratings.

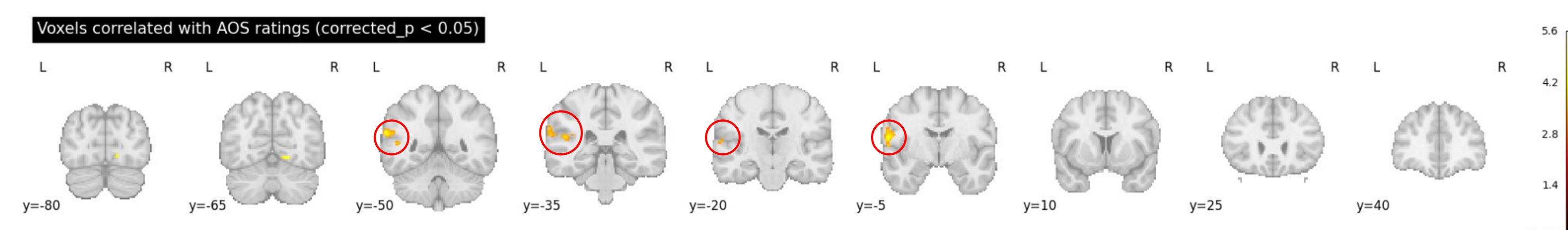

Figure 3. VBM results: Voxels significantly associated with AOS ratings.

		Size (mm3)	Center of Mass x	y	z
Expressive aphasia	cluster 1	18784	-38.2	-2.31	-18
	cluster 2	992	-25	-27.6	-9.77
AOS	cluster 1	2480	-56.2	-45.1	19.8
	cluster 2	2000	-60.1	-8.12	16.6
	cluster 3	896	14.4	-72.2	-5.82

Table 2. Clusters associated with expressive aphasia and AOS ratings.

- ❖ **Expressive aphasia**: associated with bilateral, left-lateralized cortical volumes in the temporal lobes.
- ❖ **Dysarthria:** no voxels associated with dysarthria ratings at $p < .05$, likely due to small sample size (ony 4 PPA participants with dysarthria diagnosis).
- ❖ **AOS:** associated with cortical volume in the **left PrCG**, postcentral gyrus (**PoCG**), supramarginal gyrus (**SMG**), and angular gyrus (**AG**).

Analysis 2: Relationship between volume of significant clusters and SLP ratings
- ❖ The sensorimotor PrCG/PoCG cluster ($p = 0.006$) and the parietal SMG/AG cluster ($p = 0.003$) both accounted for unique variance in AOS ratings, **suggesting** that **multiple processes** contribute to speech motor planning.

Analysis 3: Brain areas associated with length effect
- ❖ Length effect score (phonological working memory): associated with volume of the parietal cluster ($p = 0.003$) - **larger cortical volumes associated with smaller length effects**, but not with the sensorimotor cluster ($p = 0.598$).

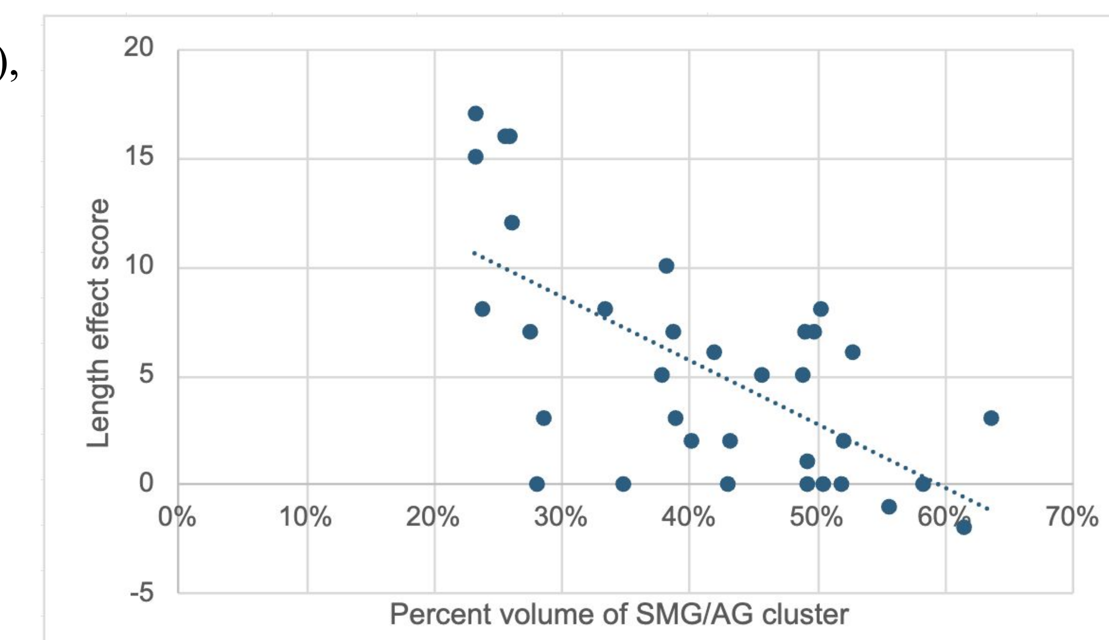

Figure 3. Volume of parietal SMG/AG cluster vs length effect scores.

Discussion

- ❖ AOS was significantly correlated with cortical volume in
  - ➢ left PrCG, the motor cortex.
  - ➢ left PoCG, the somatosensory cortex.
  - ➢ left SMG, associated with phonological WM.
  - ➢ left AG, associated with attentional control and serial order representation and processing.
  - ➢ The neural data indicates that speech motor planning consists of multiple dissociable sub-processes.
  - ➢ **Novel evidence of the role of SMG/AG in speech motor planning from PPA.**
- ❖ Phonological WM, as measured by length effect, was **uniquely** associated with the SMG/AG (and not sensorimotor areas).

Future directions
- ❖ Investigate the other processes that are involved in speech motor planning, in particular the one(s) supported by the sensorimotor cluster.
- ❖ Investigate whether if the phonological working memory involved in speech motor planning is input-/output-specific, using a picture naming task (output phonological WM) and a WM probe task (input phonological WM).

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