Speech Error Monitoring Relies on the Integrity of Anatomical Connections to Bilateral Frontal Brain Regions

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Introduction

- Speech error detection (SED) is essential for effective communication and is often impaired by strokes that cause language deficits (i.e. aphasia) [1,2].
- Activity in the medial-frontal brain regions is associated with SED [3,4]. However, their role in aphasia is unclear, as these regions are not typically damaged directly by strokes that cause aphasia [5].
- A study in our lab showed that lesions to medial frontal white matter impair SED [6], suggesting a role of anatomical connections to medial frontal regions.
- We investigated whether integrity of anatomical connections to medial-frontal brain regions correlates with SED performance in adults with aphasia from chronic left-hemisphere stroke in a whole-connectome analysis.

Methods

Participants

- 36 survivors of chronic left-hemisphere stroke (>6 months) and 38 age- and education-matched healthy controls.
- Analyzed detection rate in participants who committed at least 5 of the following error types: All Errors (n=36), Phonological errors (n=29), or Semantic errors (n=17).

Stroke Survivor Demographics By Error Type	All Errors (n=36)	Phonological Errors (n=29)	Semantic Errors (n=17)
Age: mean (SD)	60.1 (9.5)	58.8 (9.1)	58.5 (9.1)
Handedness: mean (SD)	75.7 (48.4)	80.2 (41.6)	77.4 (51.2)
Gender	23 M 13 F	19M 10F	11M 6F
Years of Education: mean (SD)	16.2 (3.2)	16.2 (3.3)	16.2 (3.2)
Months Since Stroke: mean (SD)	47.3 (40.9)	43.9 (37.1)	44.3 (41.7)
Lesion Volume in voxels: mean (SD)	7213 (5768)	7787 (5702)	7678 (5215)

Behavioral Testing

- Participants completed a confrontation picture naming test
- SED was measured as volunteered acknowledgment of one's own speech errors without any influence from the examiner (e.g., "dog….no that's not right!")

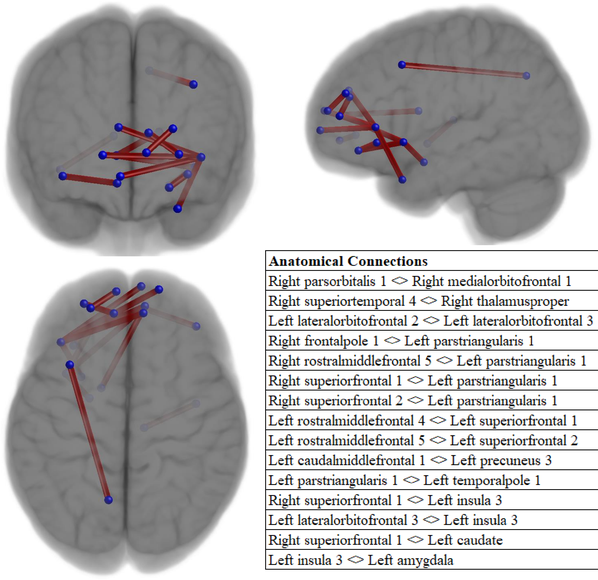
Data Analysis

- Anatomical connectomes were derived in MRtrix3 [7] using constrained spherical deconvolution and anatomically-constrained probabilistic tractography of diffusion weighted images.
- Connections between Lausanne atlas parcels (scale 125) were analyzed if present in 100% of control connectomes.
- Support-vector regression connectome-symptom mapping identified connections in which the loss of apparent fiber density was associated with poor SED.
- Regressions were corrected for lesion volume, with continuous family wise error rate=.05 at v=10 based on 10,000 permutations.

Results

- The maps for detection of All Errors and Phonological Errors were significantly non-random (Omnibus tests).
  - 15 connections survived thresholding in each analysis.
- The map for Semantic Errors was nonsignificant.

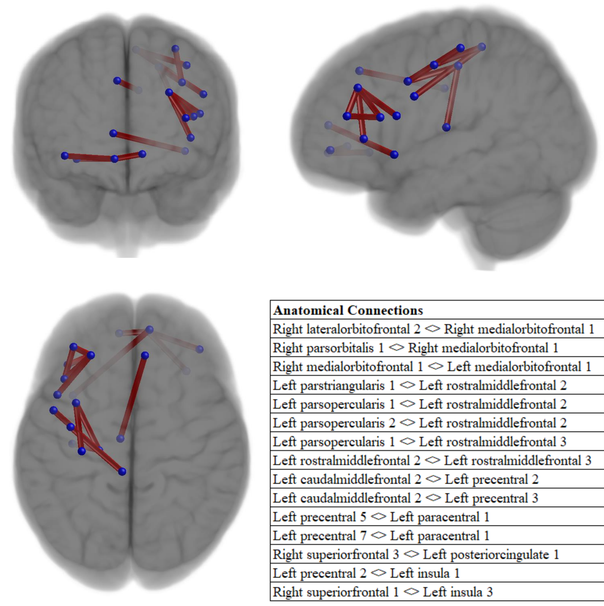
Detection of All Errors



Anatomical Connections	MNI Coordinates
Right parsorbitalis 1 <> Right medialorbitofrontal 1	{39, 38, -7} <> {8, 48, -11}
Right superiortemporal 4 <> Right thalamusproper	{39, -5, -10} <> {12, -20, 8}
Left lateralorbitofrontal 2 <> Left lateralorbitofrontal 3	{-34, 29, -5} <> {-22, 37, -13}
Right frontalpole 1 <> Left parstriangularis 1	{6, 63, -5} <> {-39, 32, 6}
Right rostralmiddlefrontal 5 <> Left parstriangularis 1	{16, 60, 6} <> {-39, 32, 6}
Right superiorfrontal 1 <> Left parstriangularis 1	{8, 51, 7} <> {-39, 32, 6}
Right superiorfrontal 2 <> Left parstriangularis 1	{9, 44, 22} <> {-39, 32, 6}
Left rostralmiddlefrontal 4 <> Left superiorfrontal 1	{-26, 50, 22} <> {-10, 58, 12}
Left rostralmiddlefrontal 5 <> Left superiorfrontal 2	{-29, 52, 8} <> {-10, 45, 20}
Left caudalmiddlefrontal 1 <> Left precuneus 3	{-37, 15, 43} <> {-10, -65, 39}
Left parstriangularis 1 <> Left temporalpole 1	{-39, 32, 6} <> {-26, 10, -29}
Right superiorfrontal 1 <> Left insula 3	{8, 51, 7} <> {-35, 12, -4}
Left lateralorbitofrontal 3 <> Left insula 3	{-22, 37, -13} <> {-35, 12, -4}
Right superiorfrontal 1 <> Left caudate	{8, 51, 7} <> {-15, -5, 11}
Left insula 3 <> Left amygdala	{-35, 12, -4} <> {-22, -5, -20}

Results (cont.)

Detection of Phonological Errors



Anatomical Connections	MNI Coordinates
Right lateralorbitofrontal 2 <> Right medialorbitofrontal 1	{33, 28, -7}<>{8, 48, -11}
Right parsorbitalis 1 <> Right medialorbitofrontal 1	{39, 38, -7}<>{8, 48, -11}
Right medialorbitofrontal 1 <> Left medialorbitofrontal 1	{8, 48, -11}<>{-10, 49, -5}
Left parstriangularis 1 <> Left rostralmiddlefrontal 2	{-39, 32, 6}<>{-28, 37, 35}
Left parsopercularis 1 <> Left rostralmiddlefrontal 2	{-42, 21, 18}<>{-28, 37, 35}
Left parsopercularis 2 <> Left rostralmiddlefrontal 2	{-45, 12, 17}<>{-28, 37, 35}
Left parsopercularis 1 <> Left rostralmiddlefrontal 3	{-42, 21, 18}<>{-39, 39, 21}
Left rostralmiddlefrontal 2 <> Left rostralmiddlefrontal 3	{-28, 37, 35}<>{-39, 39, 21}
Left caudalmiddlefrontal 2 <> Left precentral 2	{-36, 8, 42}<>{-19, -24, 55}
Left caudalmiddlefrontal 2 <> Left precentral 3	{-36, 8, 42}<>{-31, -23, 61}
Left precentral 5 <> Left paracentral 1	{-39, -8, 50}<>{-7, -36, 61}
Left precentral 7 <> Left paracentral 1	{-48, 2, 32}<>{-7, -36, 61}
Right superiorfrontal 3 <> Left posteriorcingulate 1	{8, 34, 41}<>{-8, -15, 36}
Left precentral 2 <> Left insula 1	{-19, -24, 55}<>{-38, -19, 11}
Right superiorfrontal 1 <> Left insula 3	{8, 51, 7}<>{-35, 12, -4}

Conclusion

- Disconnections of medial-frontal regions in both hemispheres, and lateral frontal disconnections in the left hemisphere are associated with reduced detection of all errors in aphasia
- Disconnections of left lateral-frontal and to some right lateral/medial-frontal regions are related to reduced detection of phonological errors.
- The importance of connectivity to bilateral frontal brain regions for speech-error detection in aphasia supports a critical role of executive networks in speech error monitoring.

Selected References

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