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Using Unsupervised Dimensionality Reduction to Identify Lesion Patterns Predictive of Post-Stroke Aphasia Severity

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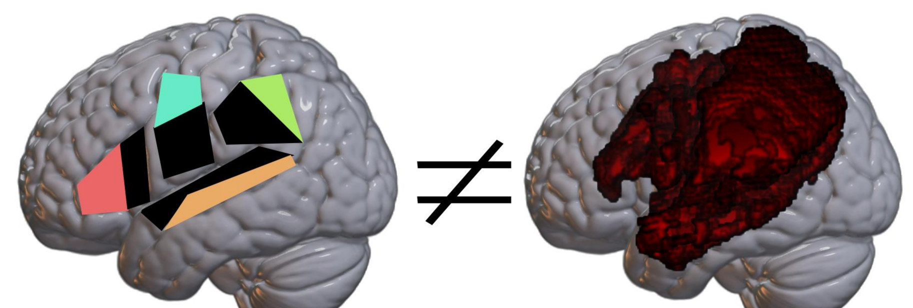
BRAIN RECOVERY

Introduction

- Voxel-based methods traditionally used to identify brain regions associated with language + other behavioral functions
  - Can predict specific deficits (eg auditory processing), but struggle to predict overall language impairment[1]
  - Often overfit to regions closer to vasculature[2] and do not represent realistic patterns of damage across the brain
  - Impairment is not the sum of damage to individual regions
- Large left hemisphere measures (eg lesion volume) correlate more with general language ability, but are too broad for accurate predictions



Non-Negative Matrix Factorization (NMF)

- Dimensionality reduction method similar to PCA, but non-negativity constraint ensures parts-based representation of data interpretable in terms of the original variables
- Can apply to lesion data to identify prototypical stroke patterns across patients[3,4,5]
- NMF atoms are more anatomically relevant than voxel/region-wise analysis as it considers holistic patterns of damage across the brain

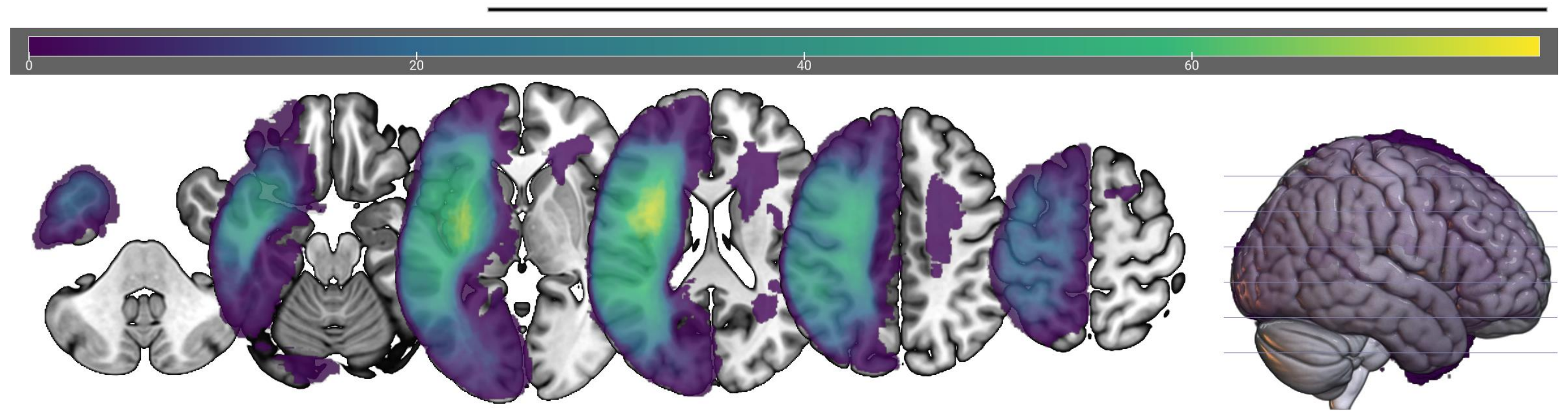
AIMS

1. Determine whether NMF representations of lesion information can better predict overall aphasia severity (WAB-R AQ)[6]
2. Identify which characteristics of stroke patterns are most associated with broad language deficits

Subjects

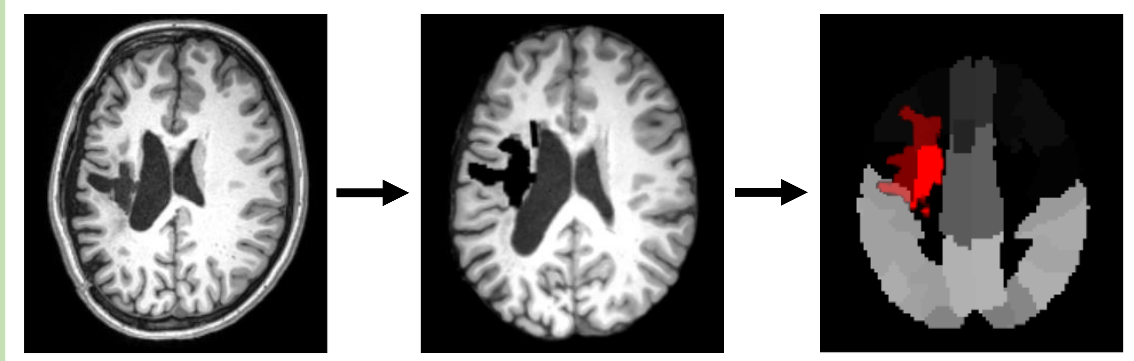
107 left hemisphere stroke patients with aphasia (76 male)

Variable	Mean (±SD)	Range
WAB-R AQ	74.12 ± 22.25	11.7-100
Age	58.64 ± 11.23	18-83
Months Post Onset	66.24 ± 69.89	3-539
Years of Education	15.89 ± 2.43	12-22
Lesion Volume (cm^3)	136.95 ± 98.68	2.03-389.41



Methods

Data Collection and Preprocessing

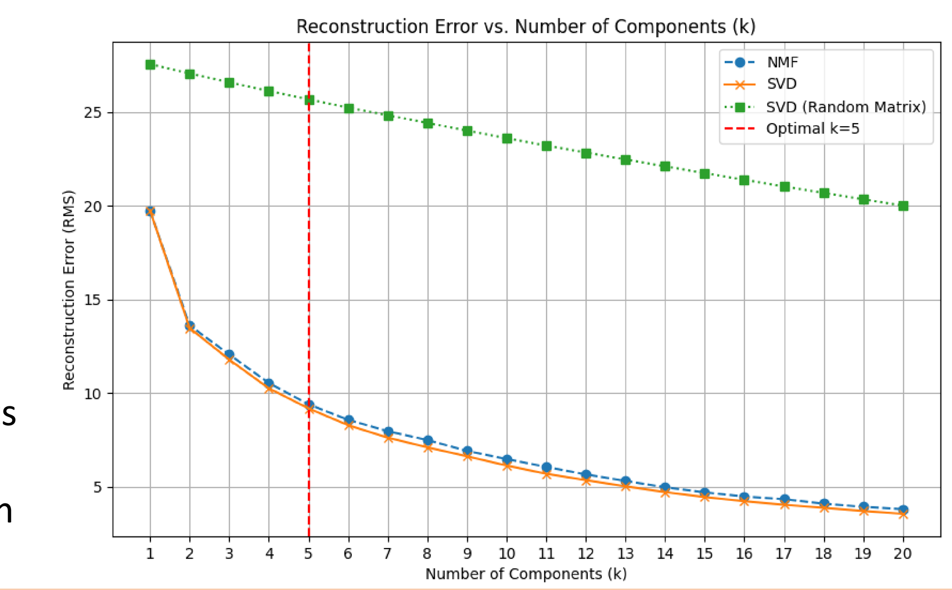


Structural MRI + WAB-R AQ Acquisition → Lesion masking, preprocessing, and registration to MNI space → *Spared tissue* per region – % lesion not overlapping gray[7] and white[8] matter atlases

NMF on Spared Tissue Data

$$X_{m \times n} \approx W_{m \times k} \times H_{k \times n}$$

X – Original data matrix
k – Number of atoms
m – Number of regions
n – Sample size
W – Component loadings (region weights per atom)
X – Patient loadings (how well each atom represents individual patient data)



*Identified optimal *k* value for dataset by comparing reconstruction error for NMF, SVD, and SVD on randomized matrix with matched mean/SD[9]

Statistical Analysis

Separate linear regressions run in R using patient loadings for each atom to predict WAB-R AQ

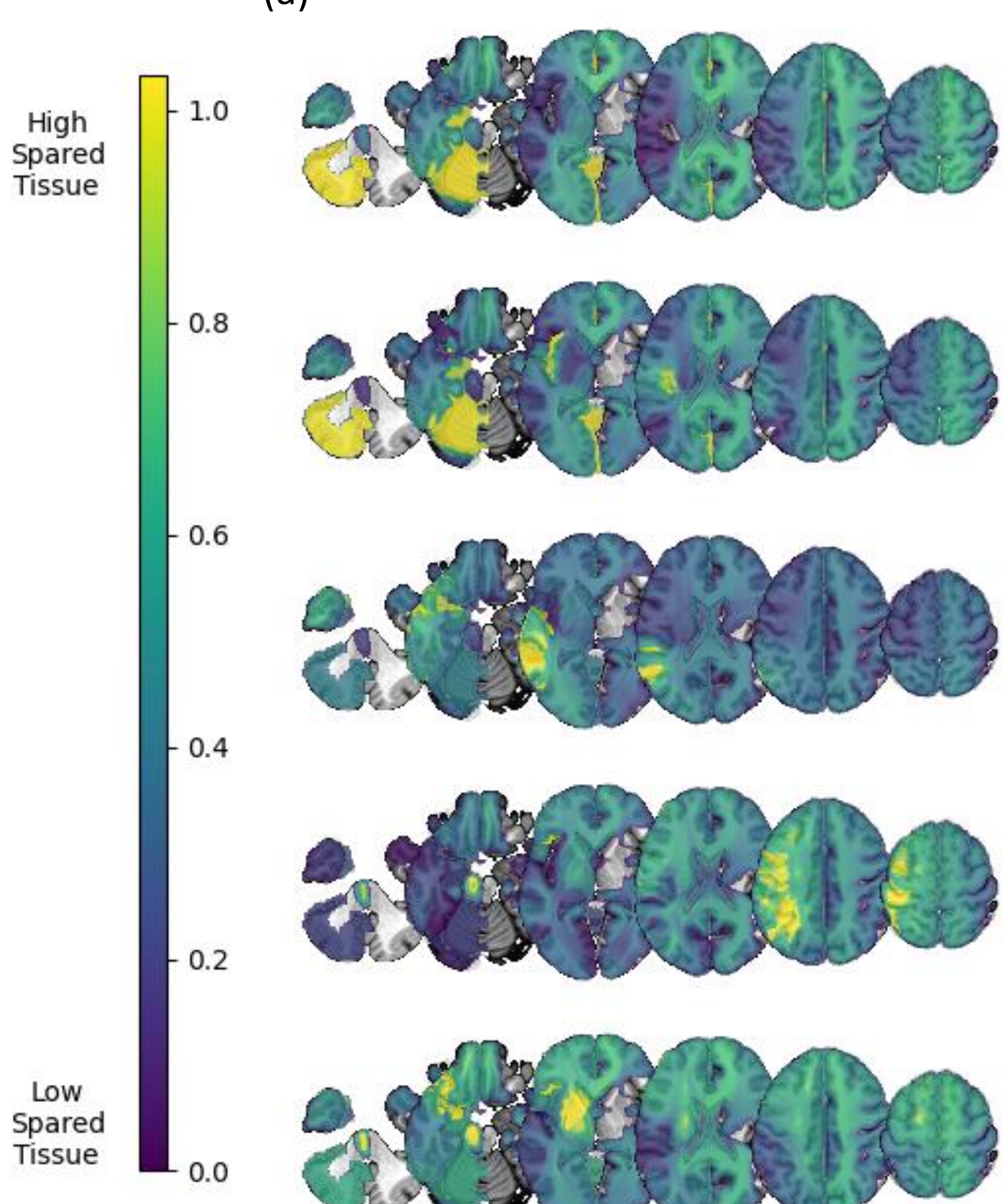
*AQ ~ age + MPO + education + gender + lesionVolume * atomLoadings*

➢ **Identify if any representative stroke patterns correlate with aphasia severity**

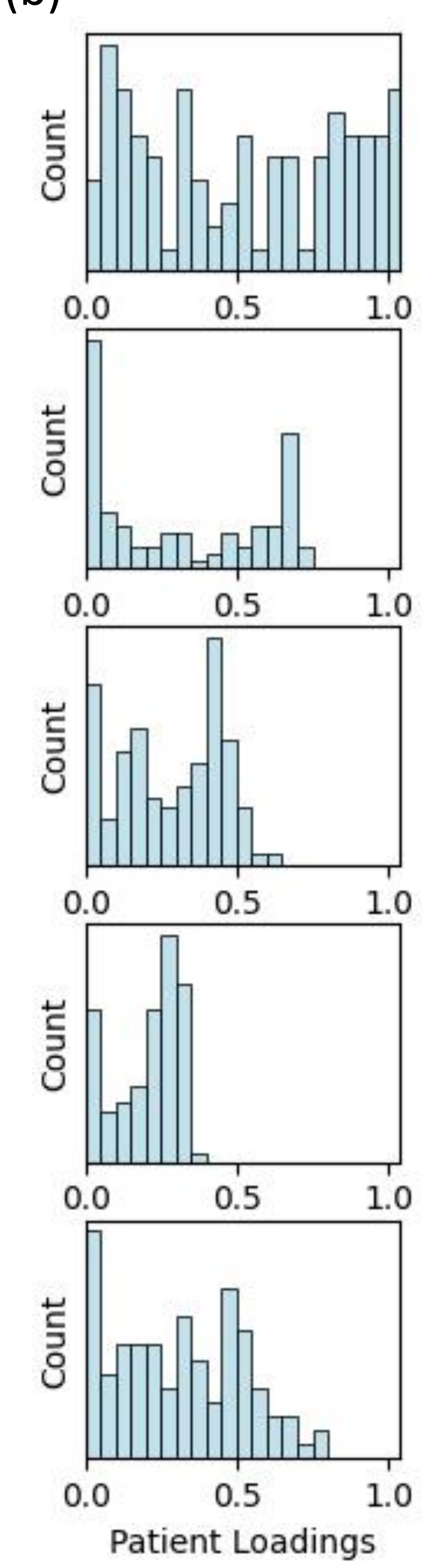
- Anova nested model comparison to test whether addition of atom terms improves accuracy over only demographics + lesion volume
- Determined correlations between patient loadings per atom
  ➢ Are certain stroke patterns overlapping or mutually exclusive?

Results

(a)



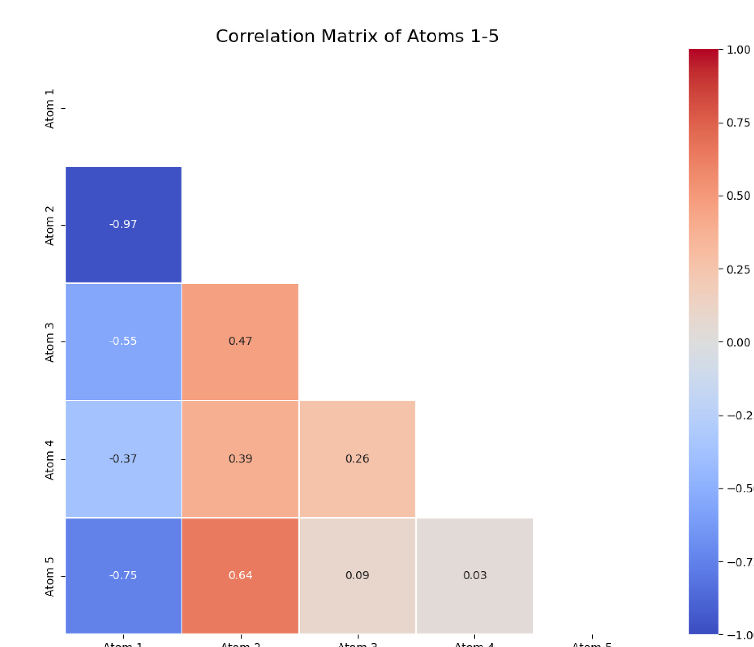
(b)



(c)

Significantly worse overall language impairment
Significantly less overall language impairment
No improvement over lesion volume + demographics
Lesion volume has a larger impact on aphasia severity
No improvement over lesion volume + demographics

(d)



a) 5 stroke patterns identified via NMF on spared tissue
b) Patient loadings per atom
c) Effect of higher patient loadings in linear regression
d) Correlations between patient loadings per atom

Conclusions

- NMF atoms integrate location + volume information, making them better predictors of AQ than either local or global lesion information alone
- Low spared tissue to the entire MCA territory is most predictive of low WAB-R AQ (atom 1)
- Spared tissue around the insula is most predictive of higher WAB-R AQ (atom 2)
- Lesion volume only has predictive value when lesions isolated to inferior language areas (atom 4)
- Future: rerun with more specific measures + recovery data to determine if any patterns are associated with specific impairments or recovery trajectory

References

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