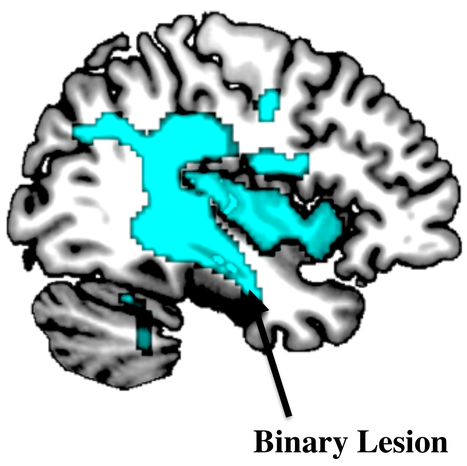
Lesions are not binary: the case for being continuous

Noor Sajid, Cathy J. Price, David Atkinson & Thomas H. Hope

Why is this important?

Researchers have tried to understand the cognitive roles that brain regions play by studying the cognitive impairments consequent to damage in those regions.

This work depends on **identifying where and how much damage has occurred.** The current, gold standard for this is the judgement of a trained neurologist, drawing lesion boundaries directly onto slices of brain images. However, the implied hard border between 'lesioned' and 'preserved' matter may not capture graded neurophysiological differences that can help explain outcomes.



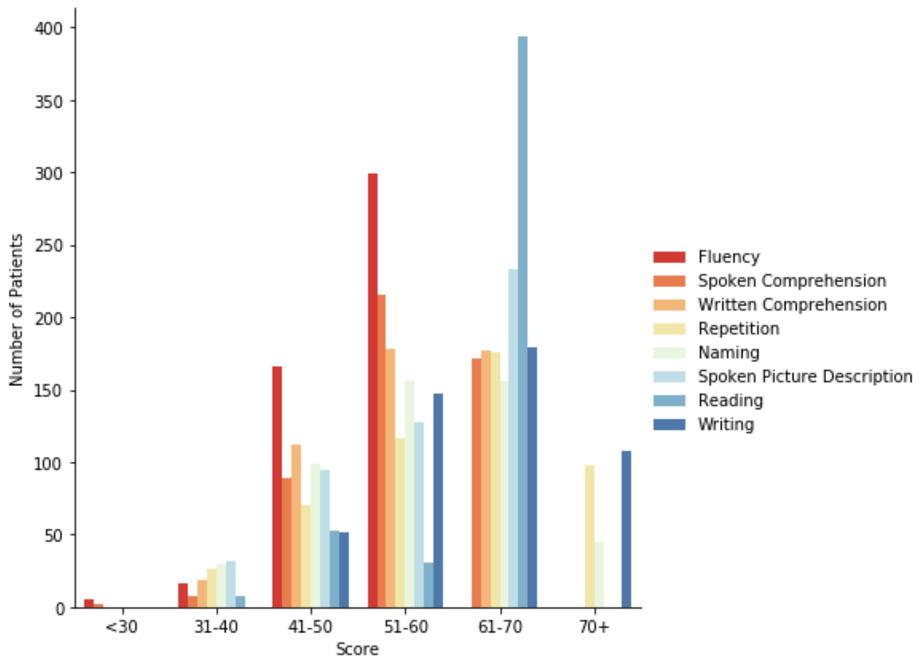
Binary Lesion

This is a missed opportunity, because the hard border between 'lesioned' and 'preserved' matter in a binary lesion image cannot capture more graded differences.

To investigate **whether (and what) brain structures beyond the binary lesion boundary contributes to language outcomes after stroke**.

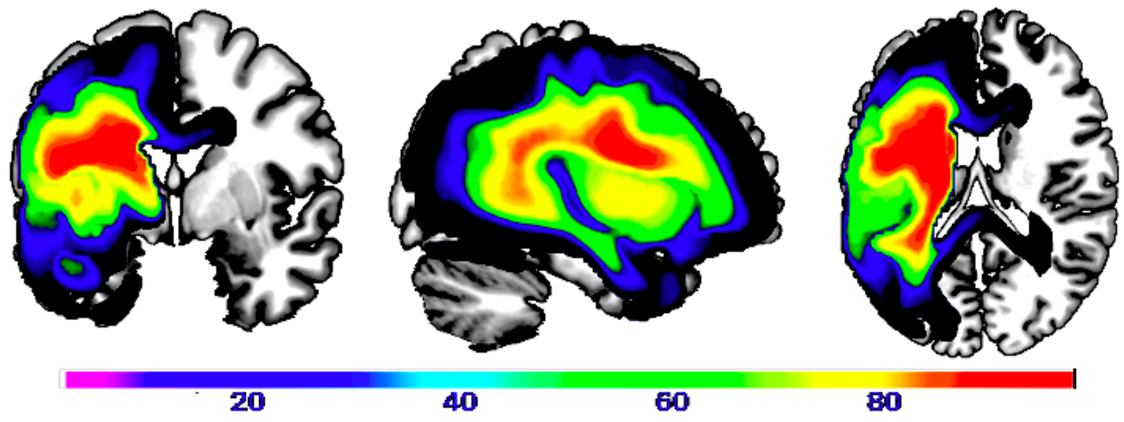
What did we do?

We studied the language outcomes of **486 post-stroke native English-speaking patients**: mean age = 55.2 ±13.5 years; mean time post-stroke = 55 ± 5 months. They had suffered (specifically left hemisphere) lesions of at least 800m^3 lesion volume (as assessed from structural MRI, using the Automatic Lesion Identification (ALI) toolbox[1]. The binary lesions derived by ALI have driven state-of-the-art predictions of language outcomes in the past[2], but the toolbox also generates more continuous evidence that each location is damaged.



Score distribution for each task across the patients

We **predicted the patients' language outcomes both with and without access to this continuous information** (outside the binary lesion boundary) using leave-one-out cross validation. From this, the 'importance map' for voxels in the fuzzy lesion space was derived using out-of-bag predictor importance method.



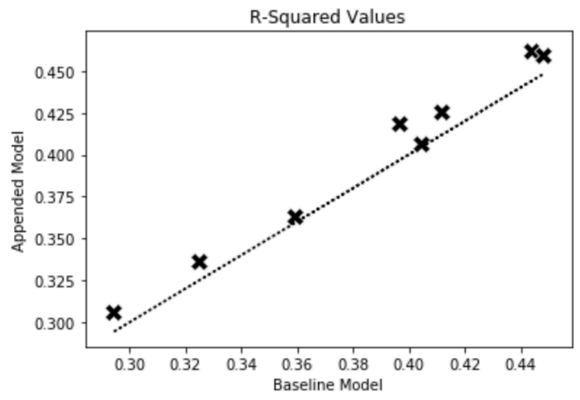
Lesion frequency image

What did we find?

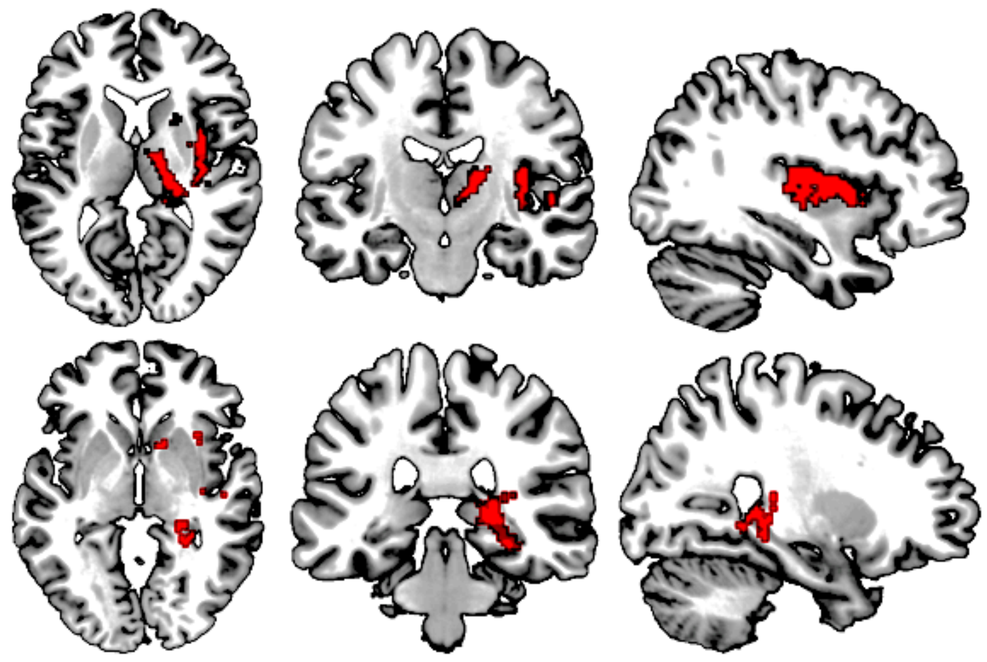
The appended model (with fuzzy lesion information + baseline model information) **made significantly better predictions** than the baseline model (with only demographic and binary lesion information) for 6/8 task scores: fluency, the comprehension of spoken and written language, repetition, naming and spoken picture description.

Task	Baseline Variation	Appended Variation	Appended P-value
Fluency	0.666	0.680	< 0.0001
Spoken Comprehension	0.570	0.580	0.0041
Written Comprehension	0.542	0.554	0.0035
Repetition	0.630	0.647	< 0.0001
Naming	0.670	0.678	0.0017
Spoken Picture Description	0.642	0.653	0.0006
Reading	0.636	0.637	0.2085
Writing	0.600	0.602	0.0918

Table 1. Results for the 8 Comprehensive Aphasia Test Behaviour Scores



Based on the Automatic Anatomical Labelling toolbox, our regions of interest in right hemisphere damaged tissue include the **right hemisphere thalamus and the insular.**



What does this mean?

Our results here suggest that more graded measures can significantly improve our ability to predict language outcomes after stroke. Since these signals are clinically useful, we suggest that lesion-symptom mapping studies should also take them into account.

Citations:
1 Seghier, M. L., Ramlackhansingh, A., Crinion, J., Leff, A. P. & Price, C. J. Lesion identification using unified segmentation-normalisation models and fuzzy clustering. *NeuroImage* **41**, 1253-1266, doi:10.1016/j.neuroimage.2008.03.028 (2008).
2 Hope, T. M. H., Leff, A. P. & Price, C. J. Predicting language outcomes after stroke: Is structural disconnection a useful predictor? *NeuroImage: Clinical* **19**, 22-29, doi:https://doi.org/10.1016/j.nicl.2018.03.037 (2018).

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