Programming Brain Mapping Hypotheses in NeuroLang

Open Science Room - OHBM 2020

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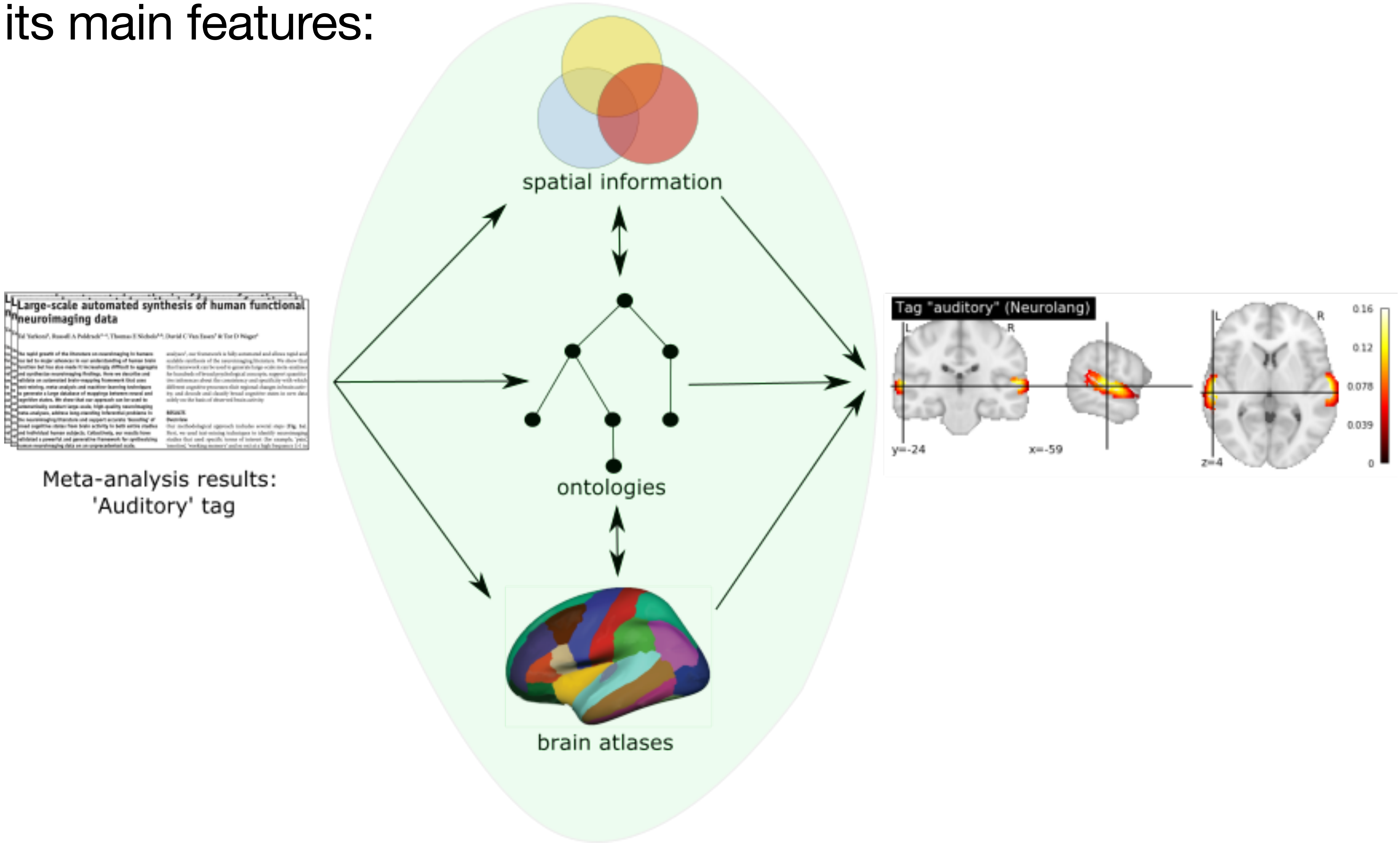
About this presentation

- NeuroLang: Probabilistic language based on Datalog$^{+/-}$ [1].
- One of its main features:



What we can achieve?

Replicating NeuroSynth[4] results

```
term_docs[term, pmid] :- \
    ns_pmid_term_tfidf[pmid, term, tfidf] & \
    term == 'auditory' & \
    tfidf > 1e-3

act_term_counts[term, voxid, agg_count(pmid)] :-
    ns_activations_by_id[pmid, voxid] &
    term_docs[term, pmid]

term_counts[term, agg_count(pmid)] :-
    ns_pmid_term_tfidf[pmid, term, tfidf] &
    term_docs[term, pmid]

p_act_given_term[voxid, x, y, z, term, prob] :-
    act_term_counts[term, voxid, act_term_count] &
    term_counts[term, term_count] &
    ns_vox_id_MNI[voxid, x, y, z] &
    (prob == (act_term_count / term_count))
```

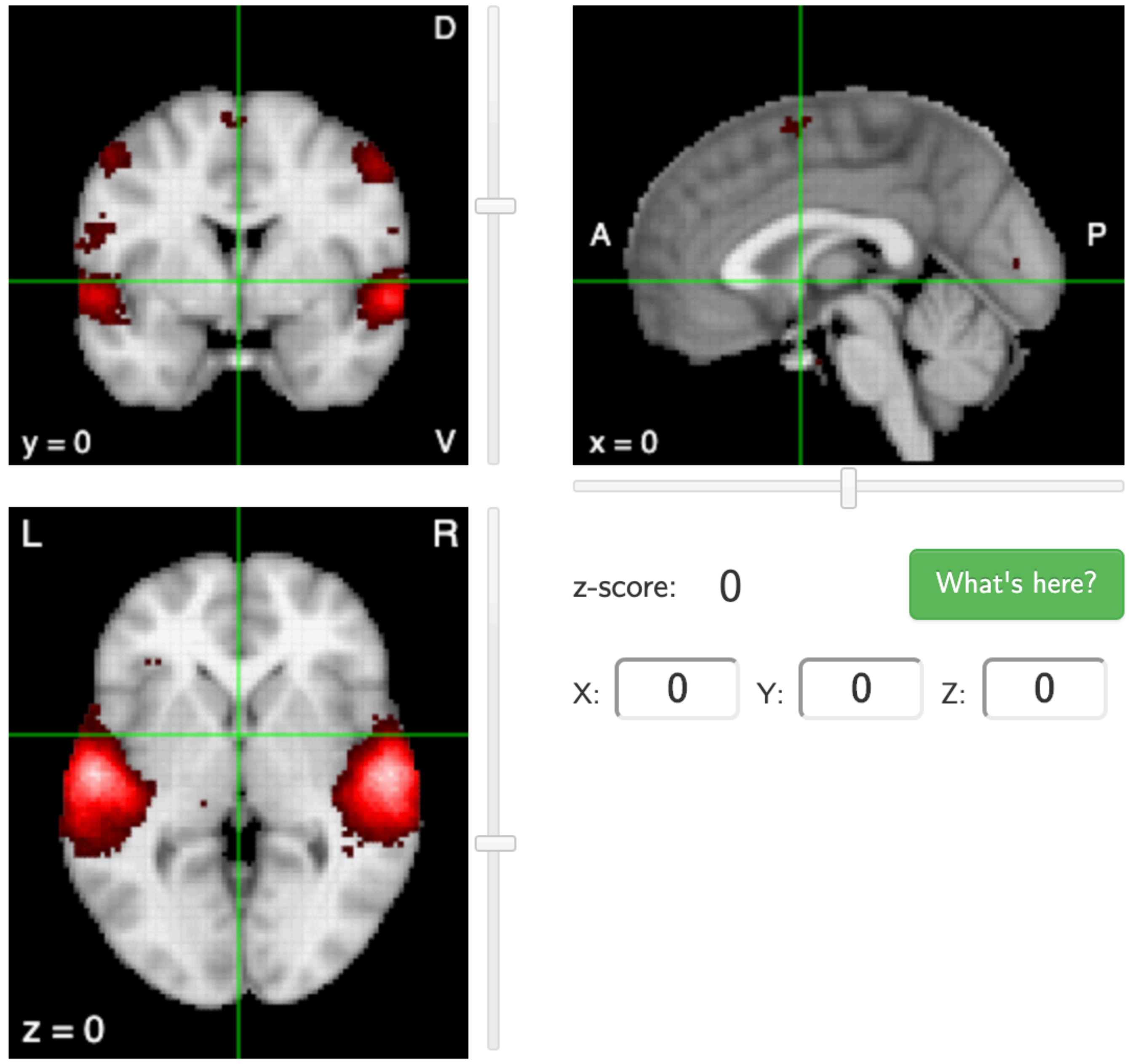
Studies that mention a given term

Counting the activations for each term

Counting terms

Probability of activation given a term*

NeuroSynth[4] results:

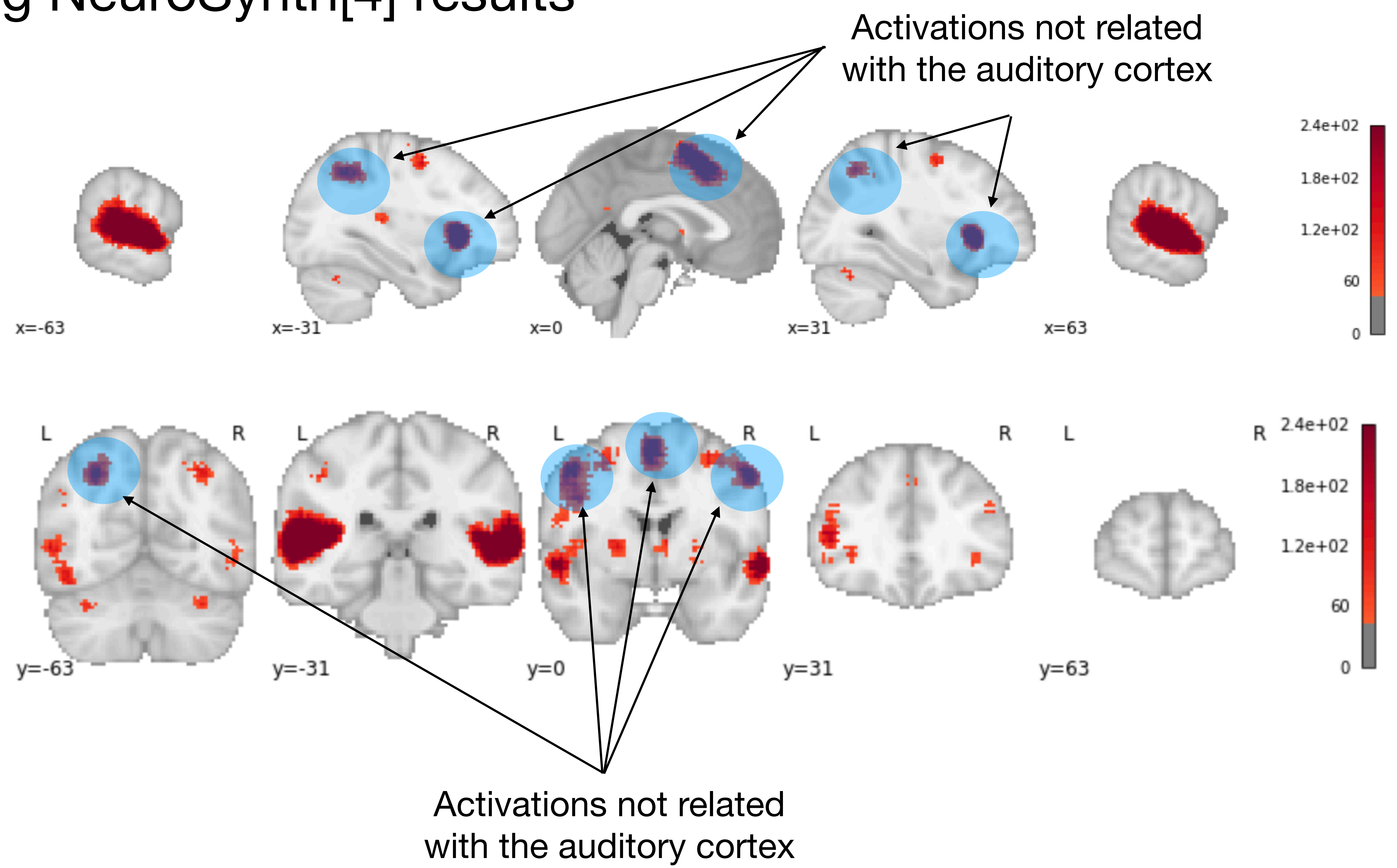


Using First Order Logic (FOL), we defined a set of implications for obtaining information from the NeuroSynth[4] database, in this case, related to the term 'auditory'.

*We are working on a probabilistic solver to avoid having to compute this information here.

What we can achieve?

Replicating NeuroSynth[4] results



What we can achieve?

Adding atlas information

First query:

```
term_docs[term, pmid] :- \
    ns_pmid_term_tfidf[pmid, term, tfidf] & \
    term == 'auditory' & \
    tfidf > 1e-3

act_term_counts[term, voxid, agg_count(pmid)] :-
    ns_activations_by_id[pmid, voxid] &
    term_docs[term, pmid]

term_counts[term, agg_count(pmid)] :-
    ns_pmid_term_tfidf[pmid, term, tfidf] &
    term_docs[term, pmid]

p_act_given_term[voxid, x, y, z, term, prob] :-
    act_term_counts[term, voxid, act_term_count] &
    term_counts[term, term_count] &
    ns_vox_id_MNI[voxid, x, y, z] &
    (prob == (act_term_count / term_count))
```

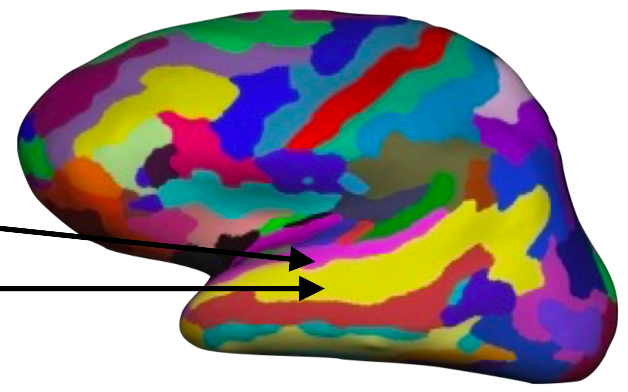
New information:

```
act_term_counts[term, voxid, agg_count(pmid)] :- \
    ns_activations_by_id[pmid, voxid] & \
    term_docs[term, pmid] & \
    filter_by_destrieux_regions[voxid, region] & \
    selected_destrieux_regions[region]
```

We have to specify each particular region by hand

In this example we selected:

- r_s_temporal_sup & l_s_temporal_sup
- r_g_temporal_middle & l_g_temporal_middle

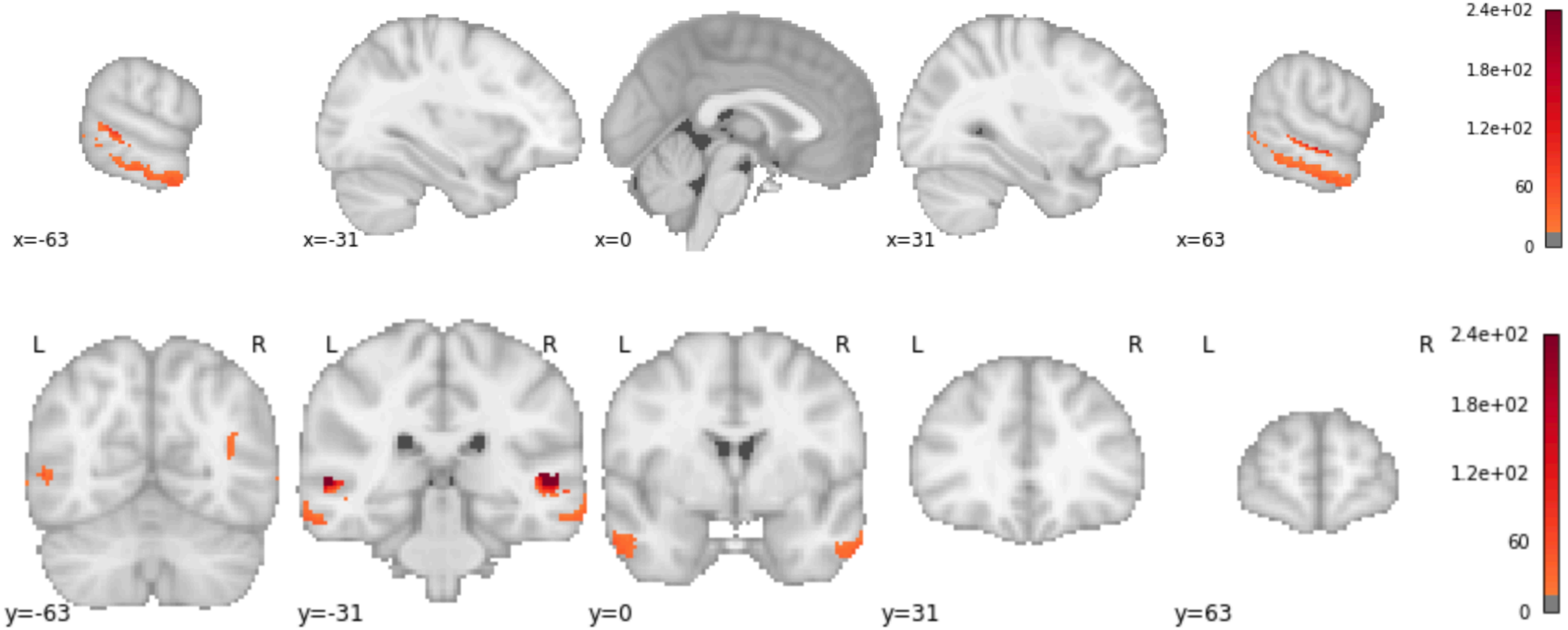


Destrieux[5] atlas

We can use spatial information from an atlas to filter the results to specific regions

What we can achieve?

Adding atlas information



- We need to address every region manually
- Error-prone

What we can achieve?

Adding ontologies

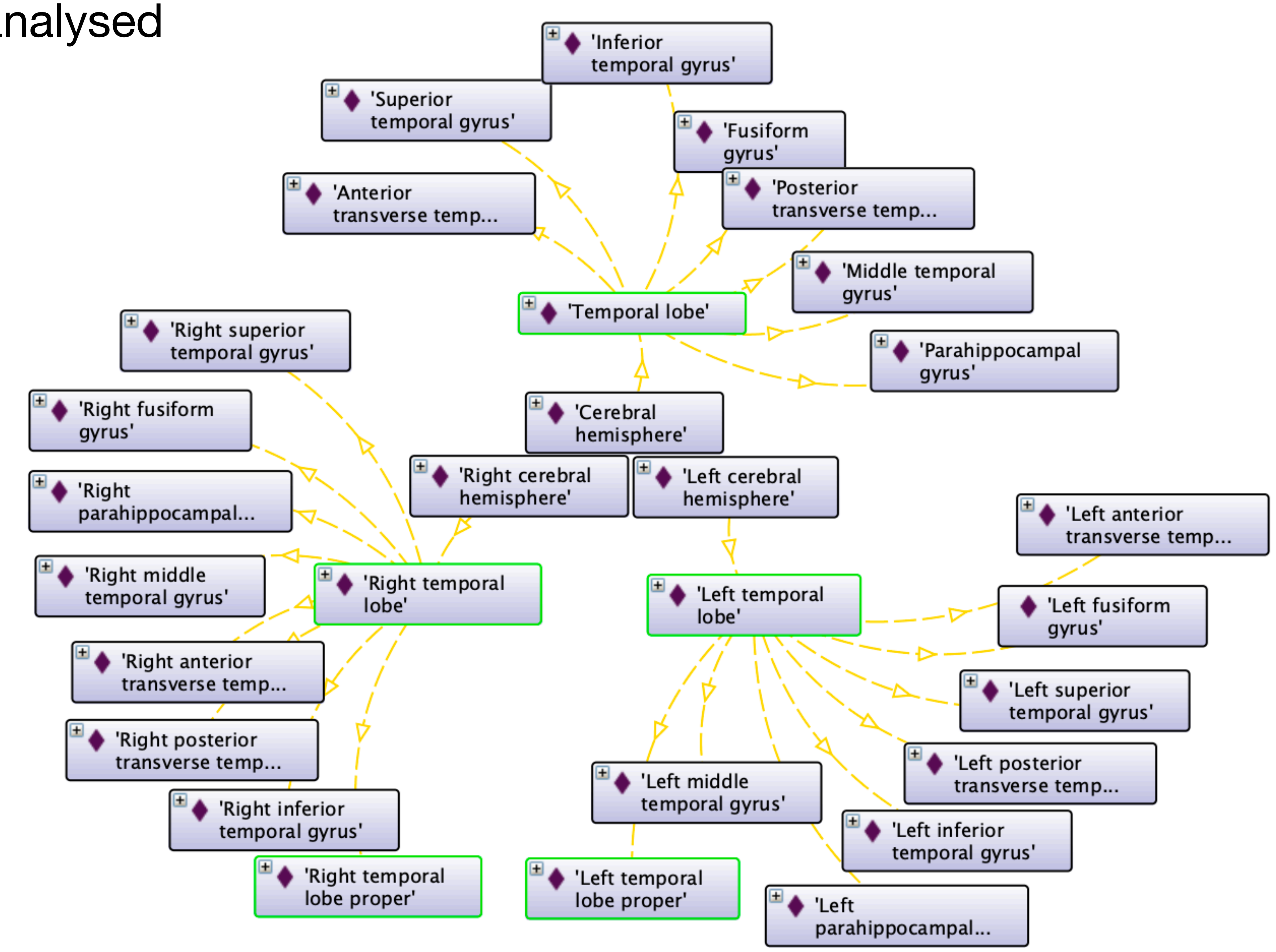
Adding priori information about the region to be analysed

```
filtered_neurosynth_ids[ns_voxid] :- \
    fma_related_region[fma_subregions, 'Temporal lobe'] & \
    fma_to_destrieux[fma_subregions, dd_name] & \
    destrieux_to_neurosynth[destrieux_name, ns_voxid]

act_term_counts[term, voxid, agg_count(pmid)] :- \
        ns_activations_by_id[pmid, voxid] & \
        term_docs[term, pmid] & \
        filtered_neurosynth_ids[voxid]
```

Complex filter based on ontology information

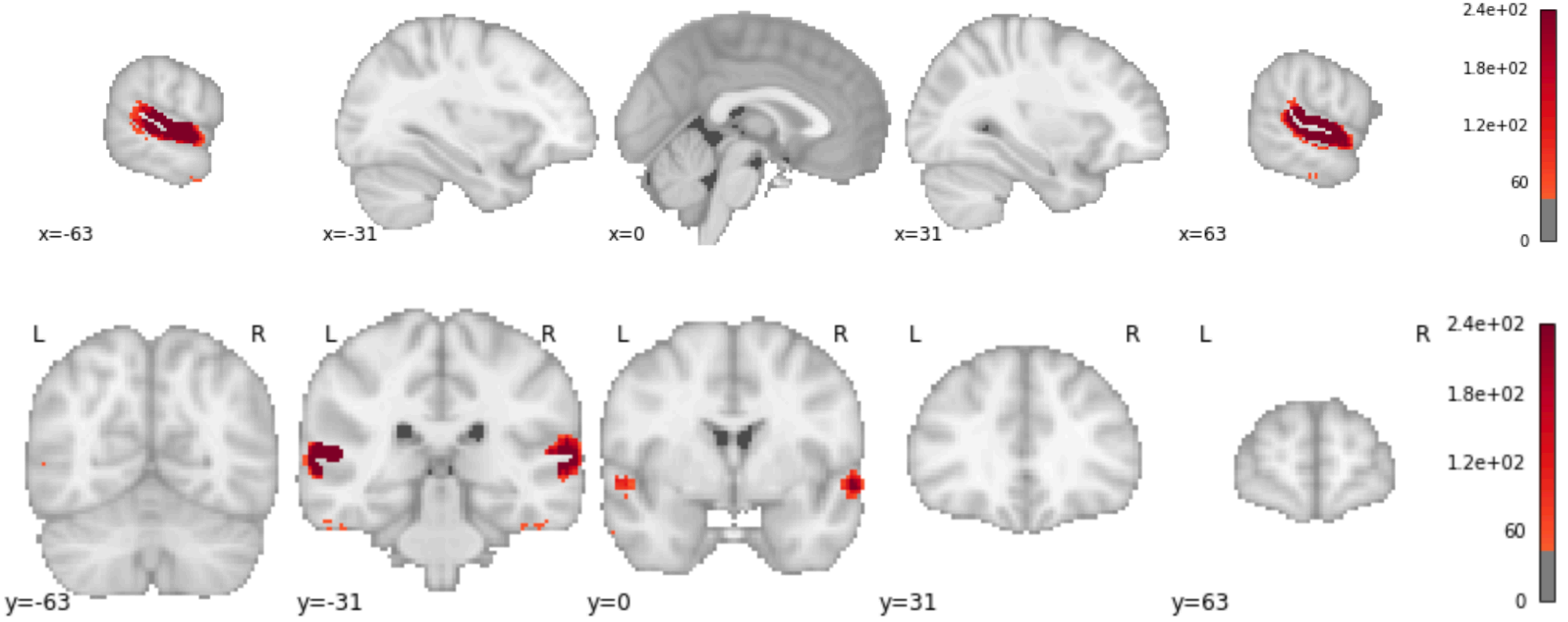
What is an ontology?
A formal way of representing knowledge in an hierarchical way in which concepts are described both by their meaning and their relationship to each other.



FMA ontology[6] subset for the “regional_part" property of the temporal lobe

What we can achieve?

Adding ontologies



- Not only useful for unifying regions
- We can use ontologies to obtain synonyms: For example 'pain' -> 'nociceptive' & ‘noxious'

NeuroLang

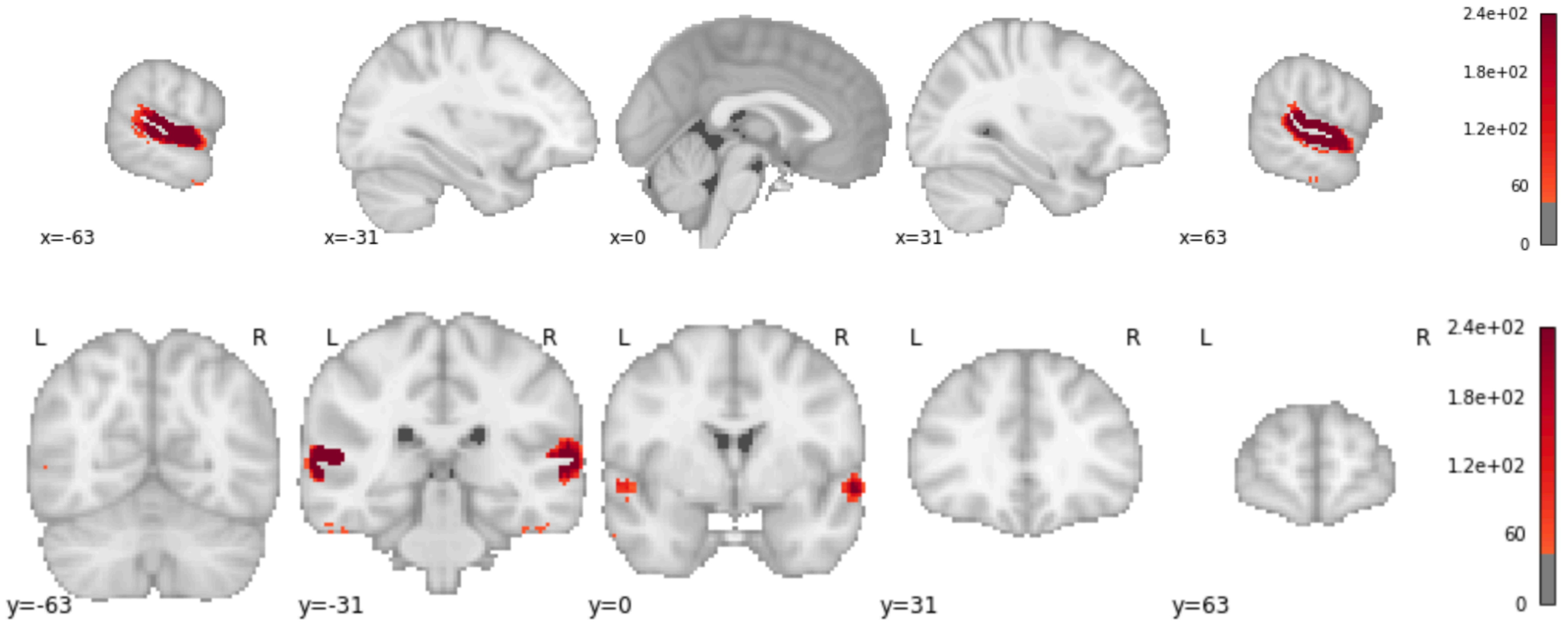
Technical interlude

- Probabilistic language based on Datalog$^{+/-}$ [1].
- Strong theoretical framework on which to develop NeuroLang, drawing on more than forty years of proven theories [2].
- An attempt to take a step in the direction of providing a unifying framework that allows researchers to represent their theories in a structured way, something that is not possible at this time [3].
- To be released as an open source tool.
- More information: https://github.com/NeuroLang or contact me: gaston.zanitti@inria.fr

One more thing…

Reverse inference

- We can continue combining information.
- Probability of a term being mention in a document given the selected activations.



	Term	Exp. Value
0	temporal	0.001400
1	magnetic	0.001108
2	resonance	0.001107
3	magnetic resonance	0.001101
4	functional magnetic	0.001053
5	using	0.001041
6	gyrus	0.001024
7	superior	0.000974
8	task	0.000973
9	auditory	0.000968
10	frontal	0.000949

Next step: Use ontologies to filter results based on cognitive processes, diseases, etc

Thanks!

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References

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3. Poldrack, R.A., Yarkoni, T.: From brain maps to cognitive ontologies: informatics and the search for mental structure. Annual review of psychology 67, 587–612 (Jan 2016).

4. Yarkoni, T.: Neurosynth core tools v0.3.1 (May 2014).

5. Destrieux, C., Fischl, B., Dale, A., Halgren, E.: Automatic parcellation of human cortical gyri and sulci using standard anatomical nomenclature. NeuroImage 53 (1), 1–15 (Oct 2010).

6. Rosse, C., Mejino, J.L.V.: The Foundational Model of Anatomy Ontology. In: Dress, A., Vingron, M., Myers, G., Giegerich, R., Fitch, W., Pevzner, P.A., Grip-pen, G., Felsenstein, J., Gusfield, D., Istrail, S., Karlin, S., Lengauer, T., McClure,M., Nowak, M., Sankoff, D., Shamir, R., Steel, M., Stormo, G., Tavar´e, S., Warnow,T., Burger, A., Davidson, D., Baldock, R. (eds.) Anatomy Ontologies for Bioinfor-matics, vol. 6, pp. 59–117. Springer London, London (2008)