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Investigating Task Effects on Brain Activity During Stimulus Presentation in MEG

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Takeaways

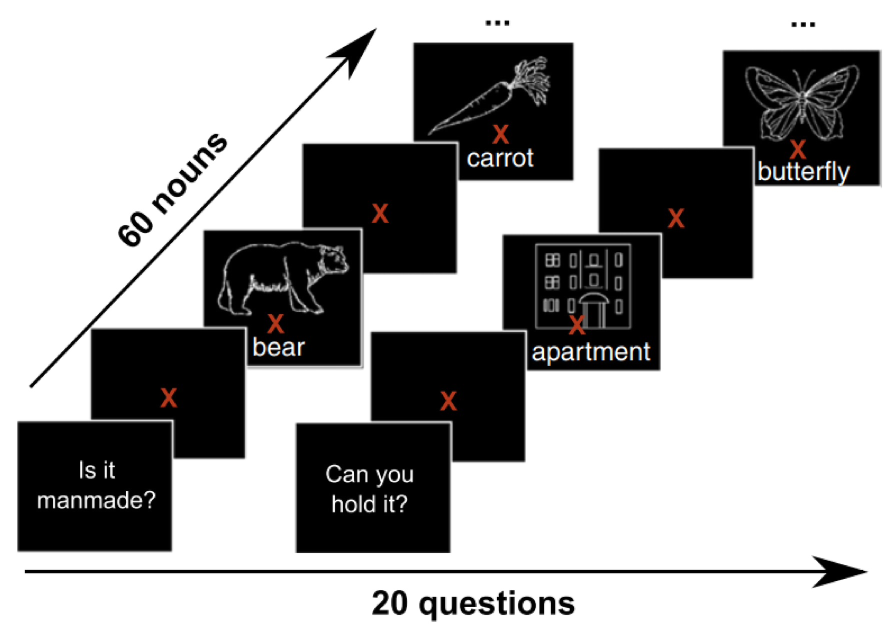
- When subjects perceive the same stimulus while performing a **task related to the stimulus semantics**, their recorded **brain activity differs across tasks**[1]
- Not well understood how the task contributes to this brain activity
- We provide a **methodology** for testing multiple hypotheses about the **interactions between the task and the stimulus semantics**
- Incorporating **task semantics** improves **single-trial MEG data prediction** by **~10%**, in a question-answering task

Brain Data

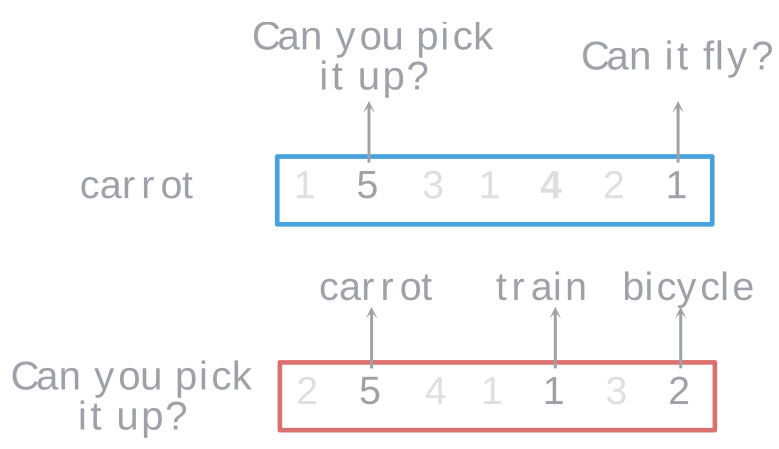
stimulus: concrete noun + line drawing

task: yes/no question about stimulus

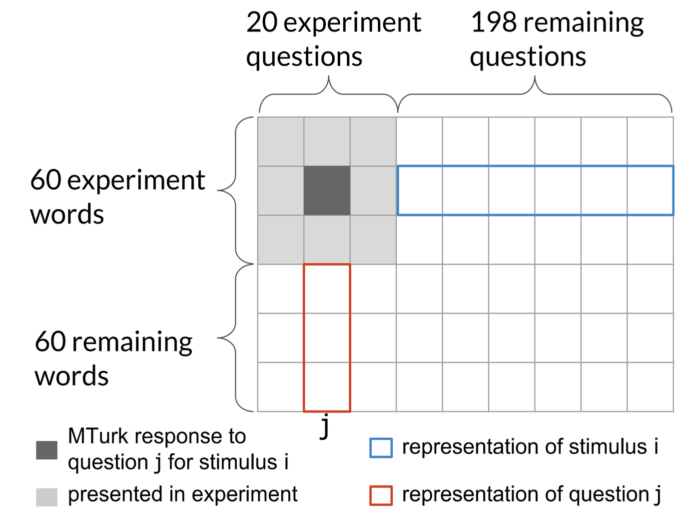
data: MEG recordings from 6 subjects[2], preprocessed with a standard pipeline



Step 1: Select representations for stimuli and tasks



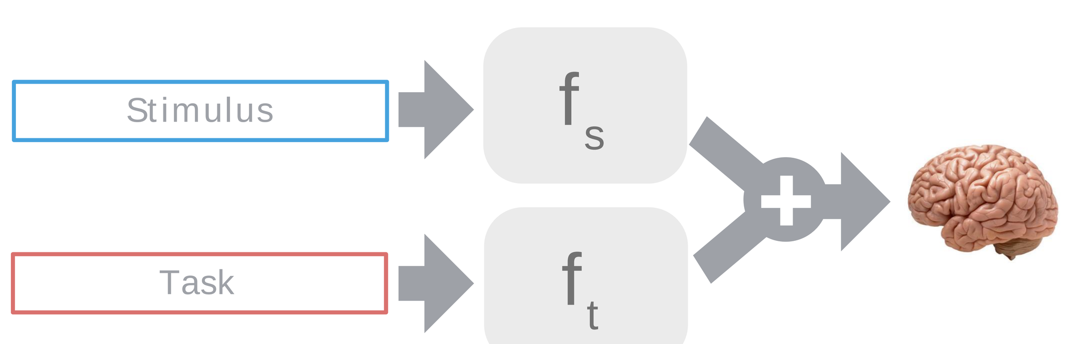
- Participants on Mechanical Turk are shown 120 words (e.g. 'bear', 'house')
- Answered 218 questions about them (e.g. 'Is it fragile?', 'Can it be washed?') on a scale 1-5.



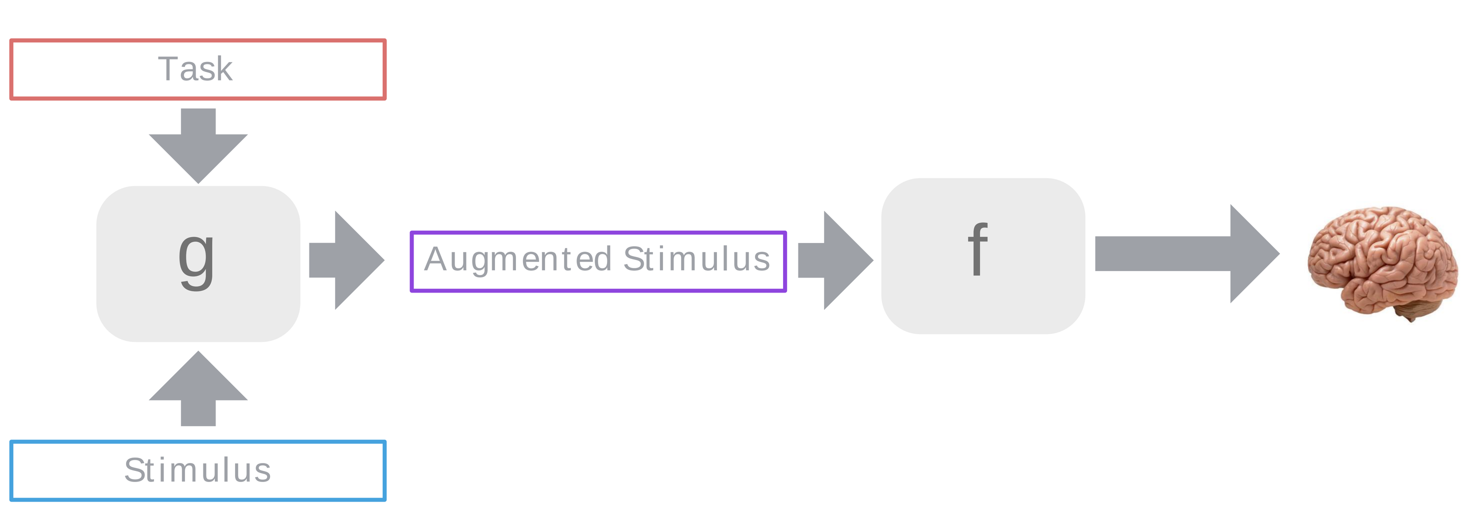
Step 2: Define computational hypotheses about task effects

- **H1**: no task effect

- **H2**: task and stimulus have independent effect



- **H3**: task changes the way the stimulus is perceived



Step 3: Predict brain recordings

- **Model**: construct loss function $\ell(x, y)$, where the input x depends on choice of hypothesis and $f(x)$ is assumed to be a linear function with parameters θ (i.e. $f_\theta(x) = \theta x$)
- **Model fitting**: minimize $\ell(x, y)$ in a leave k-out cross validation setting, leaving out 2 stimuli with all their repetitions

true brain activity — predicted brain activity — regularization on the regression parameters

$$\ell(x, y) = ||y - f_\theta(x)||^2 + \lambda||\theta||^2$$

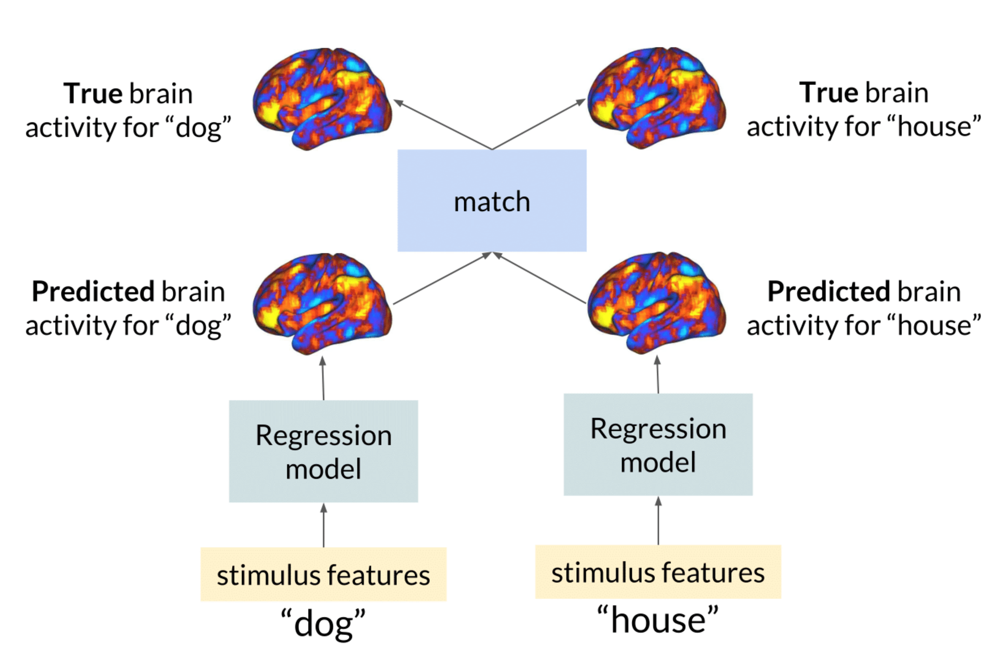
H1: $x = s$

H2: $x = [s; t]$

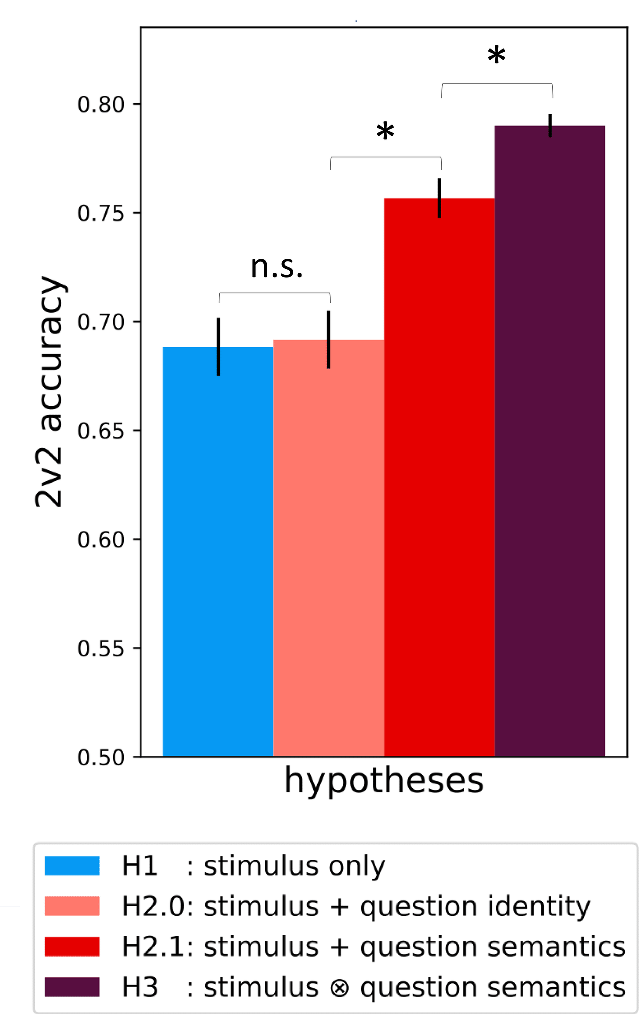
H3: $x = g(s, t) = \bar{s} = A_t s$

learnt task-dependent attention weights

Step 4: Evaluate predictions



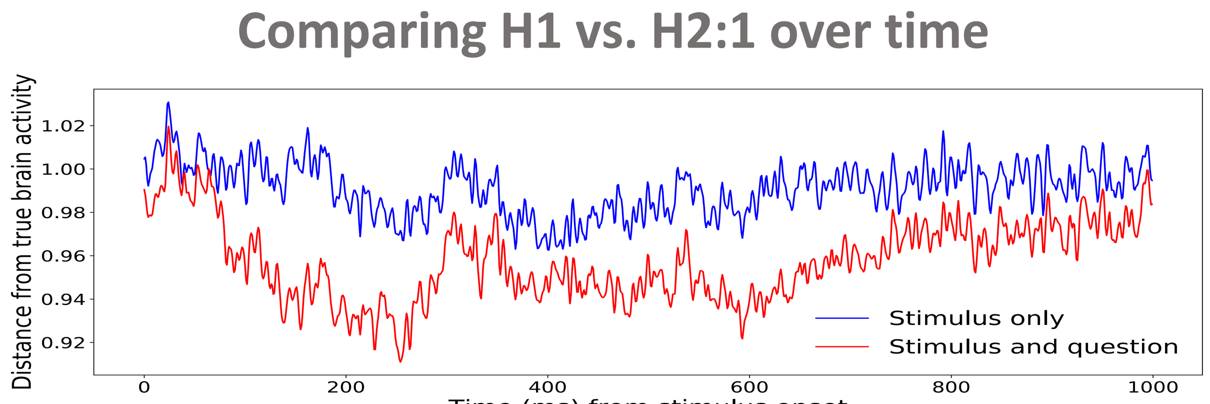
Evaluating predicted brain activity using the 2 vs. 2 metric[3]



- **Worst:** stimulus only model (**H1**)
- **Best**: interactive model (**H3**) that learns how task attends over the stimulus semantics
- Incorporating task semantics (**H2.1**) significantly improves performance, but task identity only (**H2.0**) does not.

Step 5: Interpretation

Comparing H1 vs. H2:1 over time



Distance from true brain activity for every time point after stimulus onset, averaged over MEG sensors

Notable differences in performance ~200ms and ~600ms, times when semantics of stimulus are thought to be processed[4], suggest that the task interacts with the processing of the stimulus semantics.

Conclusions and Future Work

- We **propose a framework** that enables the study of **task effects on brain activity**, and use it to investigate how question semantics affects brain response during a question-answering task.
- We show that **incorporating task semantics improves the prediction of single-trial MEG** data by an average of 10% across subjects.
- **Future direction**: conduct analyses with source-localized MEG data

Acknowledgments

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References

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