**5. General discussion**

Summary

* Listeners’ ability to adaptively change their interpretation of the speech signal as a function of recent exposure is now understood to play a central role in spoken language comprehension.
* **Our case studies suggest that existing results do not distinguish between the three mechanisms.** 
  + **One cannot draw strong conclusions about a presence or absence of representational changes from experiments on perceptual recalibration or accent adaptation**.
* But this does not mean that the three mechanisms always make the same predictions
  + Existing paradigms fall short of making/testing specific predictions as to when they make distinct predictions
* The current approach can shed light on *when* the three mechanisms make distinct predictions
  + By taking into account the (1) prior and (2) the statistics of the present speech input relative to the prior.
    - Ignoring this null hypothesis could lead to ad-hoc interpretation of data
      * Maye et al.,’s (2008) results of adaptation to vowels – actually open to multiple interpretations when the complex interactions between prior expectations and data are considered
  + Below we provide a general roadmap with 4 concrete recommendations.
    - The recommendations include steps or procedures that are currently not available
    - We then briefly discuss how integrating these recommendations may help move theoretical and empirical studies forward

**5.1 Methodological advances**

5.1.1 Dense and targeted sampling of the stimulus space

* Quantitative predictions that take into account acoustic features of input
  + Denser sampling of exposure conditions + denser sampling of test tokens
    - The more exposure conditions an experiment employs, the more accurately and reliably the parameters of the competing change models can be estimated, increasing the power of the model comparison
    - Meta-analysis

5.1.2 Data analysis beyond overall accuracy and speed

* Analyses that go beyond changes in the overall accuracy or speed of comprehension
  + Logistic regression rather than ANOVA

5.1.3 Advance standards of data annotation, reporting and sharing

5.1.4 Simulation and power analysis prior to conducting testing

* We need to know how much input is actually needed to trigger adaptation
* Perception researchers should annotate data and share them
* Or we just skip the annotation and deploy models that work with raw data or extract information automatically

In summary,

* To decisively contrast the three mechanisms, one needs to test predictions at the level of acoustic cues and speech categories
* Doing so requires new standards for experimental paradigms and data analysis

**5.2 What can we learn if we can distinguish between the mechanisms?**

* Resolving the empirical indeterminacy has far-reaching implications.
* Beyond the two paradigms that we discussed (perceptual recalibration and accent adaptation), there are many other types of experimentation that are used to examine adaptivity of speech perception.
  + One important finding is that inferred physiology or social identity affect perception.
    - These results are taken to suggest that listeners have some implicit representations of speech categories conditioned on contexts.
      * But it is not clear whether these representations are pre or post normalization
      * The current approach enables us to examine what is (or needs to be) stored/inferred (e.g., Is it cue means? Category representations? Or post-perceptual decision criteria?)
  + Nonlinguistic sounds can affect perception (Holt et al.)🡪 low-level normalization?
    - But this has been challenged
    - Under the current approach, it can be more explicitly compared against the other two possibilities
  + Clayards et al., 🡪 variance changes 🡪 representation?
    - but different types of normalization (e.g., S-cure) have not been considered
    - Results could also be predicted by decision-bias changes
* The goal of the current investigation has been to achieve strong inference through behavioral testing. But Insights derived from the behavioral research will facilitate more targeted neuroimaging research
  + Recent exposure can affect activation patterns of various areas / regions
    - But these results are hugely influenced by stimuli and tasks
      * Any of the three mechanisms could be responsible
      * Controlling stimuli and tasks 🡪 better targeting the underlying, functionally-distinct mechanisms
        + E.g., The recruitment of the post-percptual decision areas seen in Blanco-Elorrieta could be due to the fact that the stimuli involved category-level substitution. Not much adaptation can be achieved via normalization / representational changes.

Using sub-categorical “shifts” as a source of unfamiliar perceptual input would predict a proportionally stronger engagement of areas responsible for perceptual adjustments

* + - Moving away from categorical analyses and testing more detailed linking hypotheses are consonant with the idea that moving away from binary distinctions (activated or not) and conducting multivariate analyses
    - Another promising avenue is to pair temporally-sensitive techniques with imaging methods with good spatial resolution

**6. Conclusion**

* Our studies give us two take-home points
  + Much less than we thought is known about what mechanism(s) would yield types of behavioral changes we observe in speech perception experiments
    - Indeterminacy is magnified even more when we look across paradigms
      * We currently do not have strong evidence that we are actually looking at the \*same\* mechanism(s) when we examine results across paradigms.)
      * The approach we developed suggests that predictions need to be derived at the level of cues and categories
  + We \*can\* make principled inference to distinguish between the mechanisms.
    - Future research on changes in speech perception stands to benefit greatly from more rigorously defined linking hypotheses
      * Importantly, we need account for complex relations between our prior expectations and statistics of the current input
* Our inferences would always be constrained by assumptions we make about the data and computational architecture.
  + We (as researchers) need to be aware of our own theoretical biases, assumptions, and limitations.
  + What we conclude from the current investigation is that, for something as complex as human speech perception, it is hard to achieve this unless we formally represent them