ERP evidence for laryngeal underspecification in English

Arild Hestvik[1] Karthik Durvasula[1,2] Evan Bradley[1] Catherine Bradley[1]

[1]Department of Linguistics & Cognitive Science, University of Delaware [2]Department of Linguistics, Michigan State University

Aim of study

- Is the theory of **phonological underspecification** matched by the brain's encoding of phonological representations?
- Underspecification means that some features are *omitted* from the phonological level of representation (Iverson & Salmons 1995; Iverson & Ahn 2007), and then added by default rules at the phonetic level.
- For example: voiceless English stops are phonologically specified for the laryngeal feature [spread glottis], but voiced stops are underspecified for laryngeal features.
- Thus, voiced consonants differ in their laryngeal specification at the phonetic and phonological levels, whereas voiceless consonants are laryngeally specified at both levels. This sets up for an **interaction**.

How test it?

- **Phillips et al (2000):** Demonstrated that MMN paradigms where the train of standard tokens are varied within phonetic space (VOT) enforces phonological category representations.
- **Eulitz & Lahiri (2004),** Obleser et al. (2004), Walter & Hacquard (2004): Argued that in such MMN paradigms, each new stimulus token (whether standard or oddball) is temporarily phonetically represented but compared to a phonological memory trace of the series of standards.
- **Prediction** for voicing distinction in consonants:
  - A: If an oddball (specified) [t] is compared to a standard (underspecified) /d/: no conflict between voicing features.
  - B: If an oddball (fully specified) [d] is compared to a standard (fully specified) /t/: direct feature conflict.

	"T"	"D"
Phonetic level (each single stimulus event)	[t] [VOICE: spread glottis]	[d] [VOICE: Slack glottis]
Phonological level (memory trace)	/t/ [VOICE: spread glottis]	/d/ [VOICE: Ø]

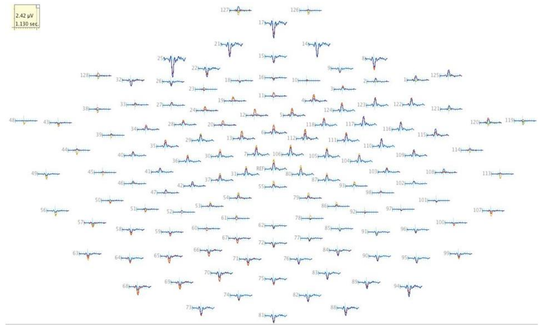
Comparison process can be thought of as feature unification (Shieber, 1986): [+F] U [Ø] = [+F] = no conflict, but [+F] U [-F] = {+F,-F} = a contradiction.

Experiment 1 (≈Phillips et al, 2000)

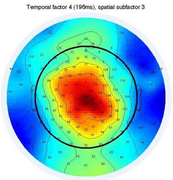
- SUBJECTS: 23 UD undergraduates (current count N=33)
- STIMULI: Subjects' VOT discrimination function first obtained in a behavioral forced choice identification task. 4 CV syllables on either side of midpoint were used as "ta" and "da" stimuli. E.g., 20, 25, 30, 35ms VOT, and 55, 60, 65, 70ms VOT.
- PROCEDURE: Two blocks of 700 standards and 100 deviants continuously presented in pseudo-randomized order through free field speakers (variable ISI; mean: 903ms; SD: 80ms). Additional target detection of a different stimulus (male vs. female "ba") interspersed among the trials. Visual feedback for targets.
- BLOCKED DESIGN: One group (N=15) heard 'd' tokens as deviant in first block, the other group heard 't' tokens as deviant in first block. (Current subject count = 17 and 16 in each group; the same pattern holds in the larger data set).
- EEG: 128 channel EGI 300 system in sound proof both. 250Hz sampling rate, open filters. 800ms epochs with 200 ms baseline; average-referenced.

Results

- PRE-ANALYSIS & DESCRIPTION: Temporal PCA identified MMN time region 100-300ms (peak 196ms). Spatial PCA on this temporal factor identified effect at central electrode region.
- *Temporal PCA factor (196ms)*



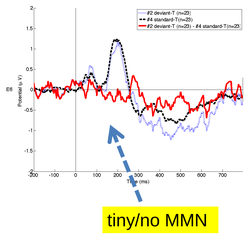
- *Spatial subfactor* :



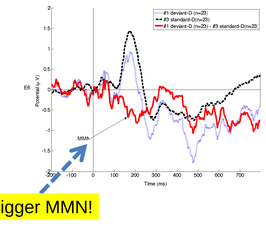
Results (contd.)

MMN at FCz:

deviant T – standard T

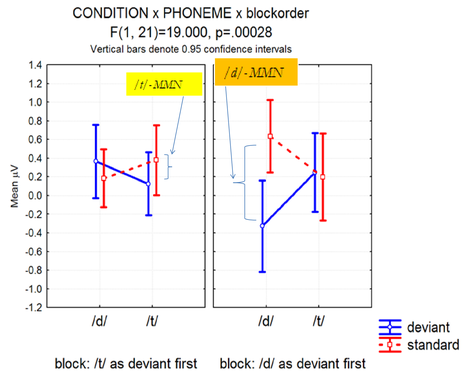


deviant D – standard D



- **ANOVA**, using mean voltage of PCA-defined MMN-region during 100-300ms as dependent measure.
  1. Main effect of CONDITION: F(1,22)=4.69, **p < .05**
  2. CONDITION x PHONEME: F(1,21)=3.0, p=.09

However, effect of mismatch was greater in 1st block With block-order factor added to ANOVA:



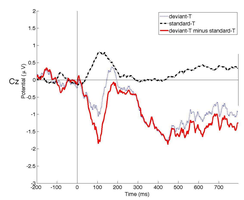
Conclusion

- Asymmetry observed between mismatch for /d/ vs. mismatch for /t/: Almost disappears for /t/, stronger for /d/.
- The Eulitz & Lahiri underspecification theory prediction is matched by observation for coronal stops.
- Note: Similar effect was also reported in Phillips et al (2000) but was noted as an unexpected observation.

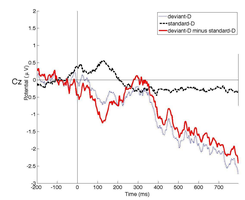
Experiment 2 (phonetic version)

- RATIONALE: The premise in Phillips et al (2000) and Eulitz & Lahiri (2004) is that varying tokens encourages phonemic memory trace representation. If we present single tokens in standard/deviant, then the MMN comparison process can rely on purely phonetic representations.
- PREDICTION: Because phonetic memory trace is fully specified, there should now be no asymmetry.
- SUBJECTS: 33 UD undergraduates
- STIMULI**: one single token of /d/ (20ms VOT) and one single token of /t/ (60ms VOT)**
- PROCEDURE & DESIGN: As in Experiment 1.

T as deviant first, t-MMN: (N=17)



D as deviant first, d-MMN: (N=16)



FINDING: No asymmetry between /d/ and /t/ in **phonetic paradigm!** Both 'd' and 't' show similar MMNs.

Current follow-up studies

- In Spanish, /d/ is specified for [slack vocal folds] and /t/ is underspecified. **Prediction**: Spanish should show the opposite asymmetry, with greater MMN for /t/ than for /d/.
- Replicating Experiment 1 with attention to "pa" rather than "ba" to rule out confound (but cf. Experiment 2)

References

Eulitz, C. & A. Lahiri (2004). "Neurobiological Evidence for Abstract Phonological Representations in the Mental Lexicon during Speech Recognition." Journal of Cognitive Neuroscience 16(4): 577-583.

Iverson, G. K. & S.-C. Ahn (2007). "English voicing in dimensional theory." Language Sciences 29(2-3): 247-269.

Iverson, G. K. & J. C. Salmons (1995). "Aspiration and Laryngeal Representation in Germanic." Phonology 12: 369-396.

Obleser, J., C. Eulitz, et al. (2004). "Magnetic Brain Response Mirrors Extraction of Phonological Features from Spoken Vowels." J. Cogn. Neurosci. 16(1): 31-39.

Phillips, C., T. Pellathy, et al. (2000). "Auditory Cortex Accesses Phonological Categories: An MEG Mismatch Study." Journal of Cognitive Neuroscience 12(6): 1038-1055.

Shieber, S. M. (1986). An Introduction to Unification-Based Approaches to Grammar. Stanford, CA, Center for the Study of Language and Information, Stanford University.

Walter, M. A. & V. Hacquard (2004). MEG Evidence for Phonological Underspecification. BioMag 2004.

Contact info: Hestvik: arild@udel.edu Durvasula: durvasul@msu.edu