UMassAmherst

ERP indices of lab-learned phonotactics

Claire Moore-Cantwell, Joe Pater, Robert Staubs, Benjamin Zobel and Lisa Sanders

RUMMIT

UMass Amherst, April 6th 2013

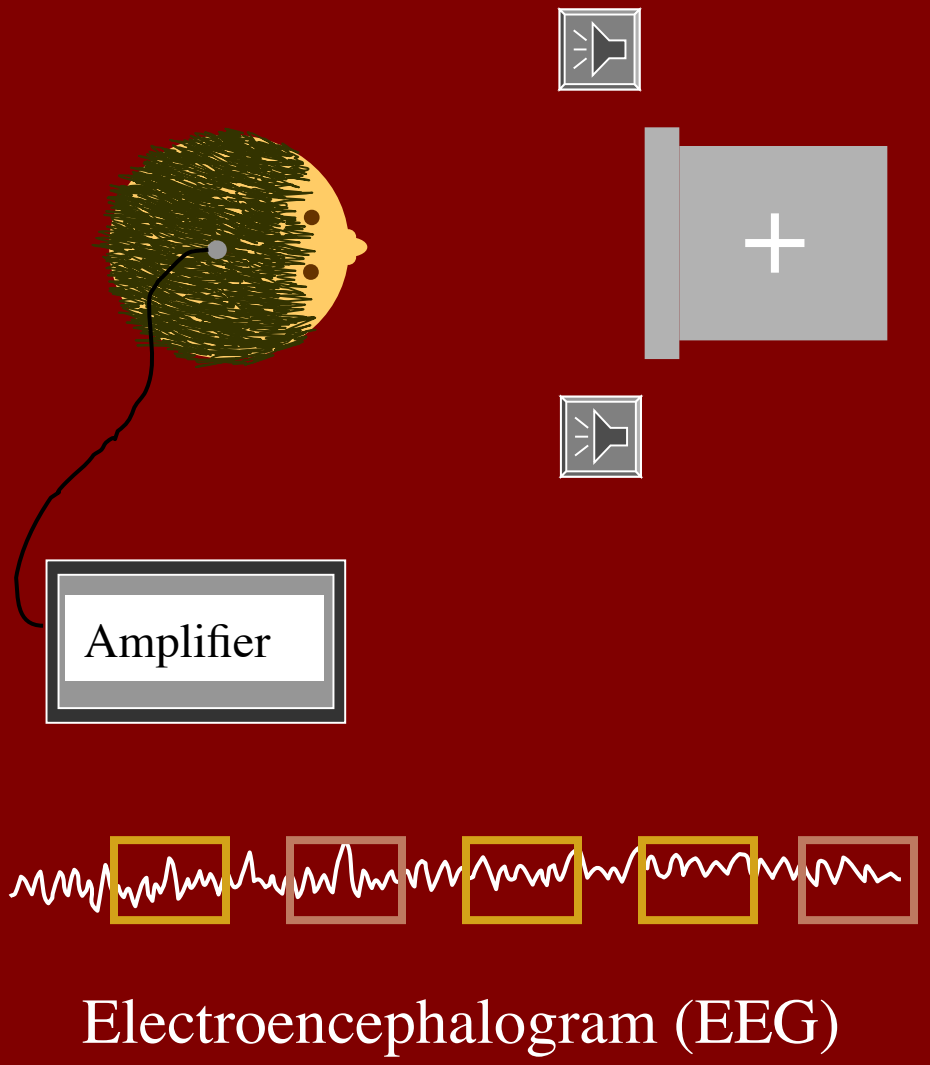
Introduction: learning phonology in the lab

- Over the last ten years, a large body of work has examined the learning of phonological patterns in the laboratory (review in Moreton and Pater 2012)
- Why study learning in the lab?
  - Tight control over learning conditions
  - Can test predictions that would be impossible to study in a natural setting
- Ecological validity?
  - Can lab findings be generalized to natural learning?

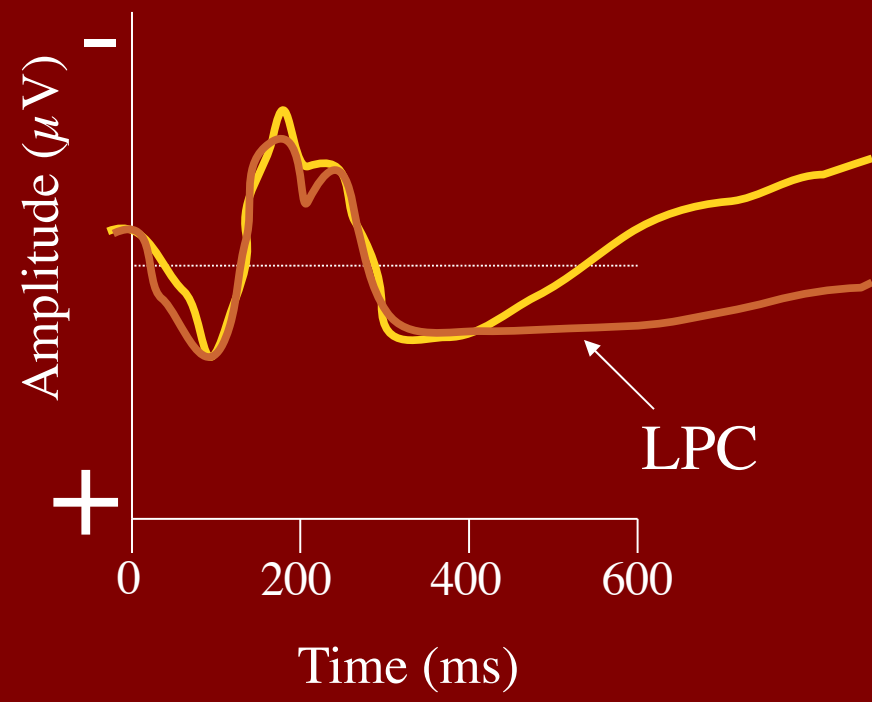
Introduction: ERP background

- **Is the neural response to a violation of a lab-learned phonotactic regularity similar to the response to a naturalistically learned one?**
- We address this question by studying Event Related Potentials (ERPs)

Event-Related Potentials (ERPs)



…*gidu*…*tægi*…*gidæ*…



Introduction: Phonotactics and ERPs

- An important distinction (but one that seems neither fully-understood nor completely crisp)

  Phonotactics that cause "perceptual repair"

  **dla* (English) **ebzo* (Japanese)

  Phonotactics that influence well-formedness judgments

  **V:mp* (English, Dutch) **skVk* (English, German)

  Vowel harmony (Finnish - has exceptions)

- When does perceptual repair happen?

  a. *Right away*

  - Dahaene-Lambertz, Dupoux and Gout (2000)
    - Oddball paradigm
    - Japanese listeners: **ebzo* → *ebuzo*

  b. *Not immediately, but still early*

  - Breen, Kingston and Sanders (2013)
    - Priming study: English **dla* → *gla*
    - Two stages
      - Veridical representation of *dla* (200 - 350 ms.)
      - Mapping to *gla* (350 - 400 ms.)

- What is the ERP index of a phonotactic violation that passes the perceptual filter?

  Late positive component (LPC)

  - McLaughlin *et al.* (2010), Pitkänen (2010)
    - Finnish nonce vowel harmony violations
    - Orthographic presentation
  - Domahs *et al*. (2009) - German **skVk* study (which we will review in detail)

- LPC also associated with syntactic violations (*AKA* P600 – see Morgan-Short *et al.* 2012 for a review) and with violations of musical expectations (review in Carrión and Martin Bly 2008)

- Our study builds on Domahs *et al.* (2009), who examined the processing of three types of sC_1VC_2 words by native speakers of German

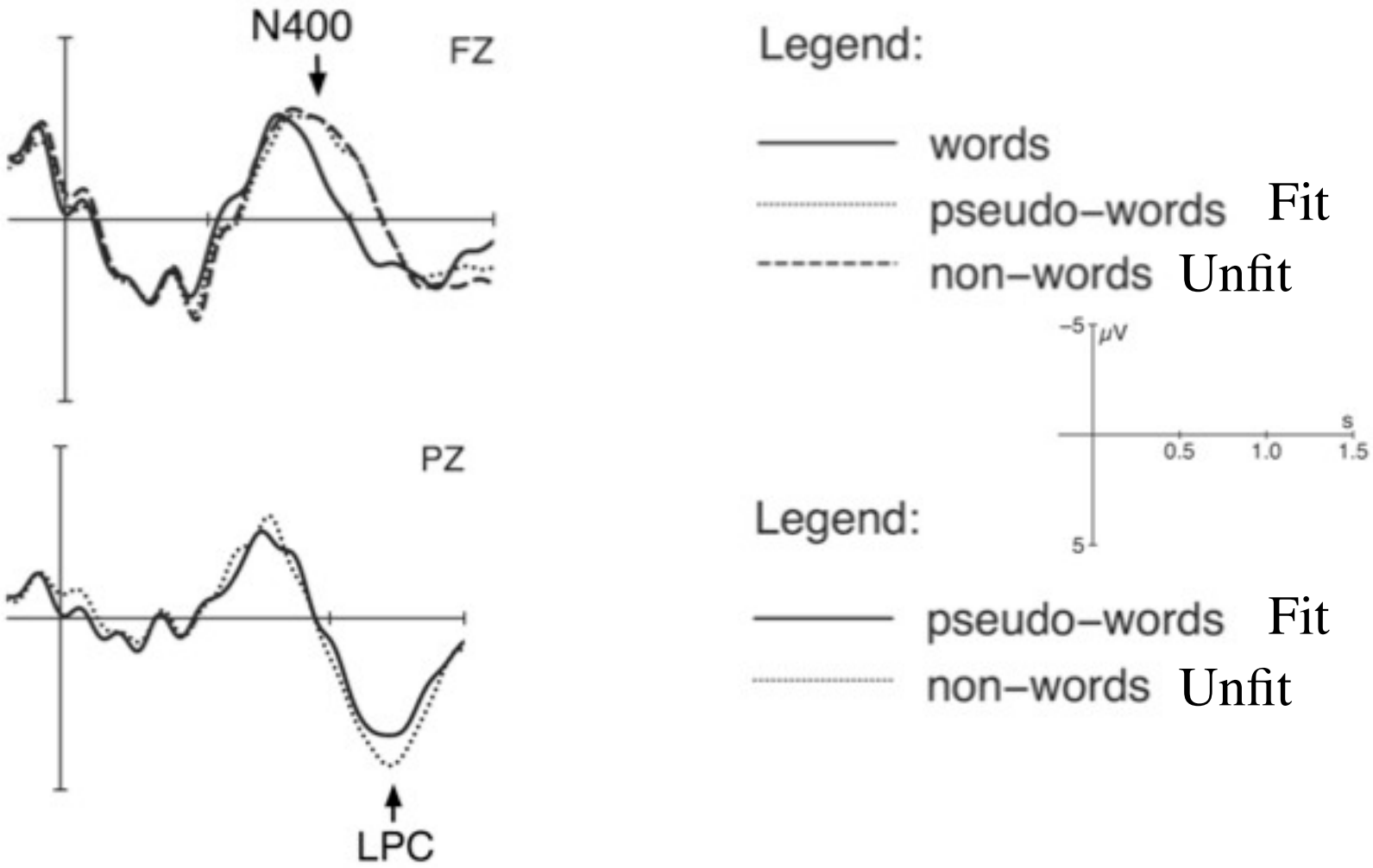
  Real words: C_1 and C_2 differing in place

  Fit nonce: C_1 and C_2 differing in place

  Unfit nonce: C_1 and C_2 same place

- Subjects performed a lexical decision task while EEG data was recorded
- N400 greater for nonce than real words, as found in many other studies
- Late Positive Component (LPC) greater for unfit than fit nonce words

- N400 *vs*. LPC:


N400
FZ
Legend:
words
pseudo–words Fit
non–words Unfit
−5 μV
s
0.5
1.0
1.5
5
PZ
Legend:
pseudo–words Fit
non–words Unfit
LPC

Our study

- Two phonotactic regularities over C_1VC_2V words

  "Assimilation"

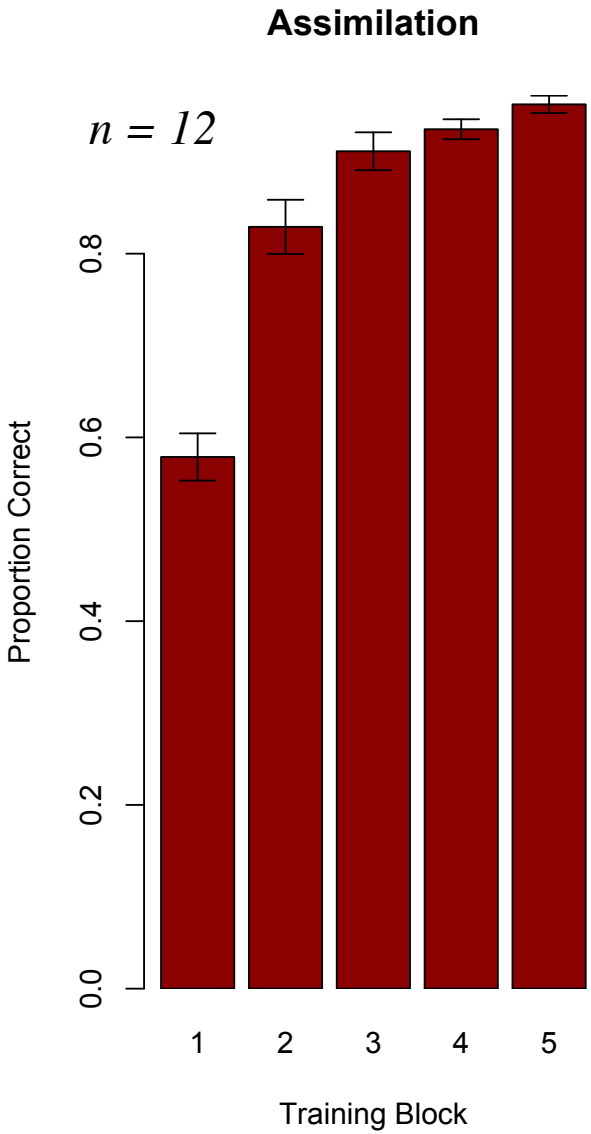
  C_1 and C_2 agree in [+/-voice]

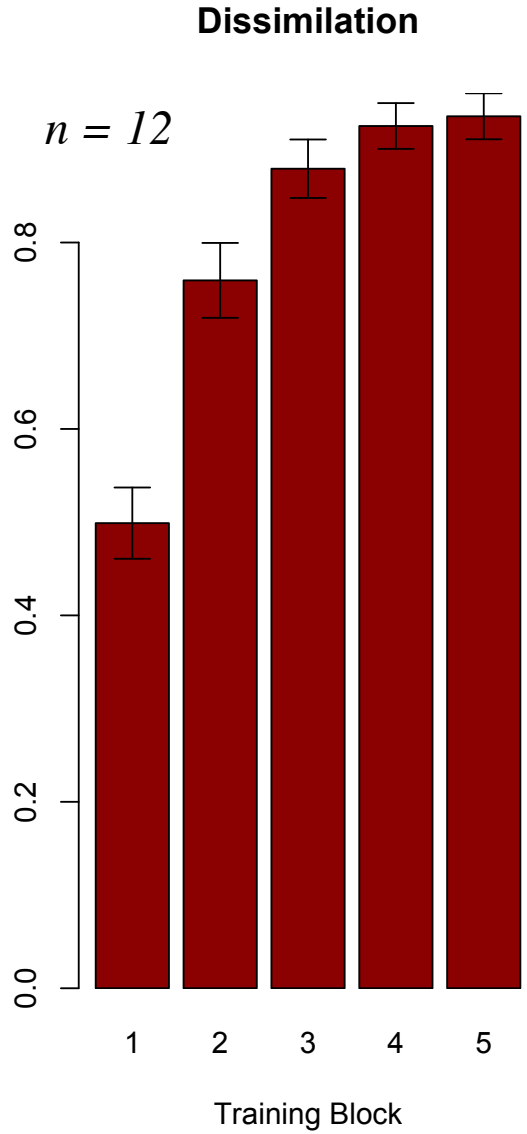
  "Dissimilation"

  C_1 and C_2 disagree in [+/-voice]
- Consonants limited to [t d k g], vowels to [i u æ ɔ]
- 8 words that fit the regularity presented in training with meaning, also presented as test items
- Novel test words include 8 fit and 8 unfit words

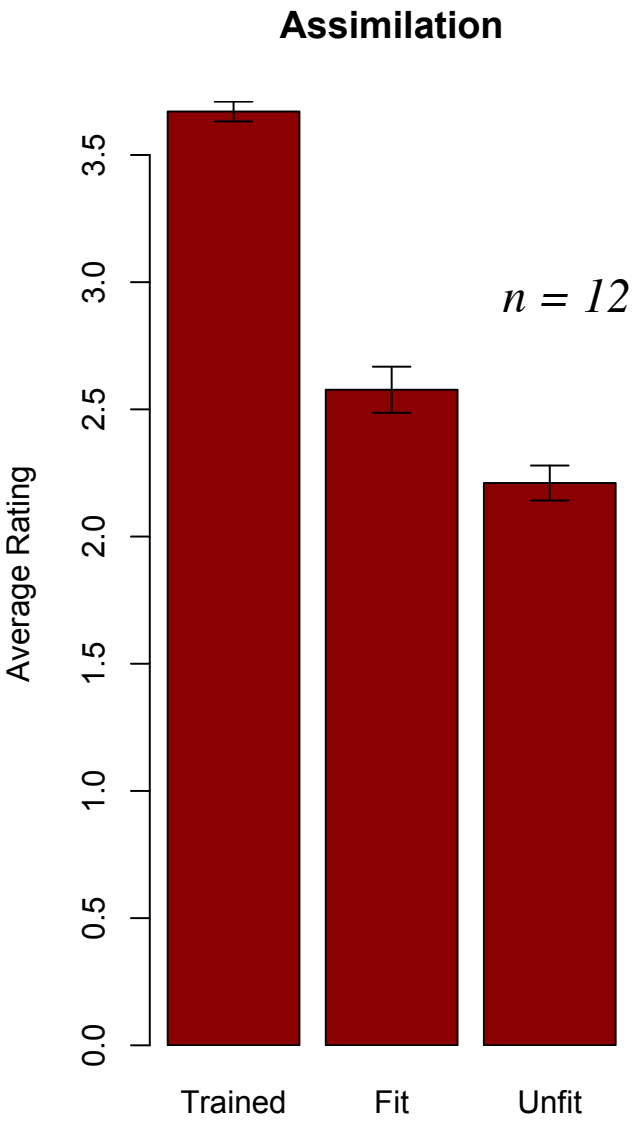
  (*counterbalanced:* fit in one condition = unfit in the other)

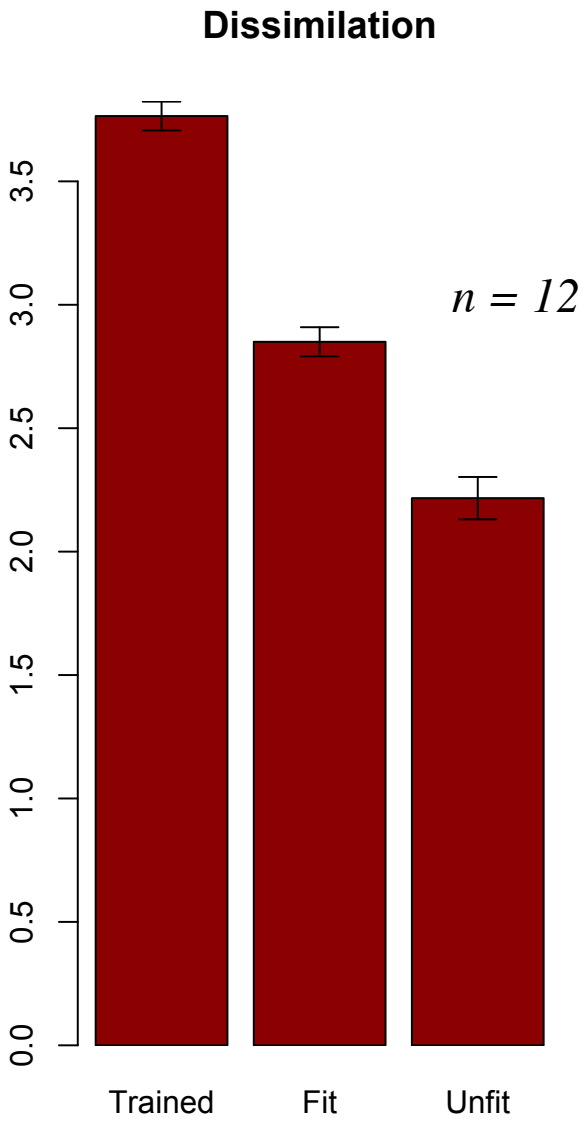
- Training:
  - Hear a CVCV word
  - See four pictures, press button to indicate correct meaning
  - See correct picture in isolation and hear word again
  - In one block, 10 trials of 8 words (80 trials)
- Testing:
  - Hear a trained, fit, or unfit word
  - Rate (1-4) likelihood that the word is in the language
  - In one block, hear 8 words of each category


Assimilation
n = 12
Proportion Correct
0.0
0.2
0.4
0.6
0.8
1
2
3
4
5
Training Block


Dissimilation
n = 12
0.0
0.2
0.4
0.6
0.8
1
2
3
4
5
Training Block

- The subjects learned the meanings of the words very quickly - even in the first block, they were well above chance (0.25)
- This rapid learning was important because it means we can average ERPs across all five of the testing sessions. The pattern of learning was similar across the assimilation and dissimilation conditions

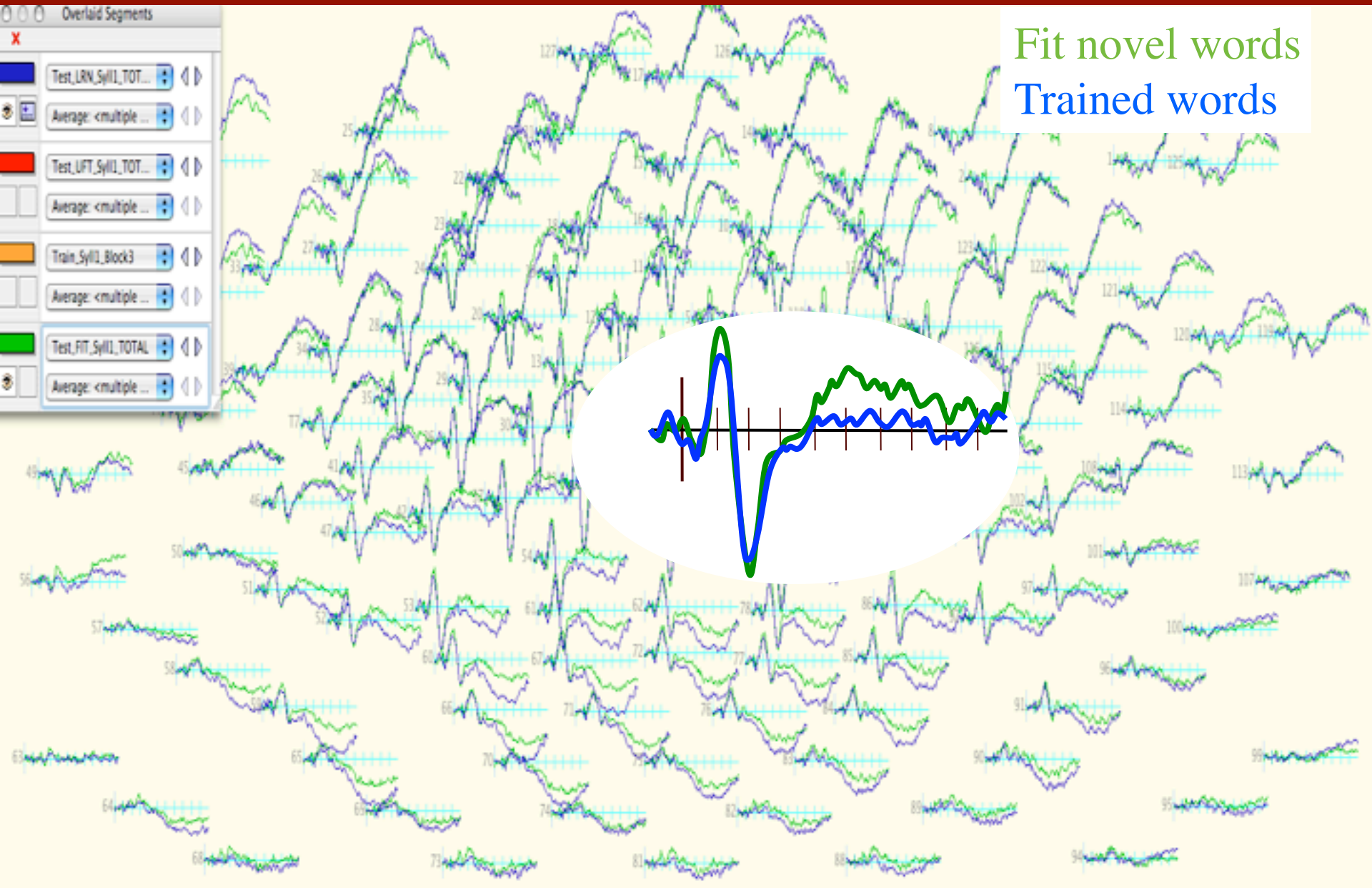

Assimilation
Average Rating
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
n = 12
Trained
Fit
Unfit


Dissimilation
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
n = 12
Trained
Fit
Unfit

- Preliminary statistics indicate that ratings of conforming nonce words are significantly higher than nonconforming for both Assimilation ($t(11) = 3.64$, $p < .01$) and Dissimilation ($t(11) = 5.70$, $p < .001$)
- A two-way ANOVA with Language as a between-subjects factor and Fit as a within-subjects factor revealed no interaction ($p > .50$)

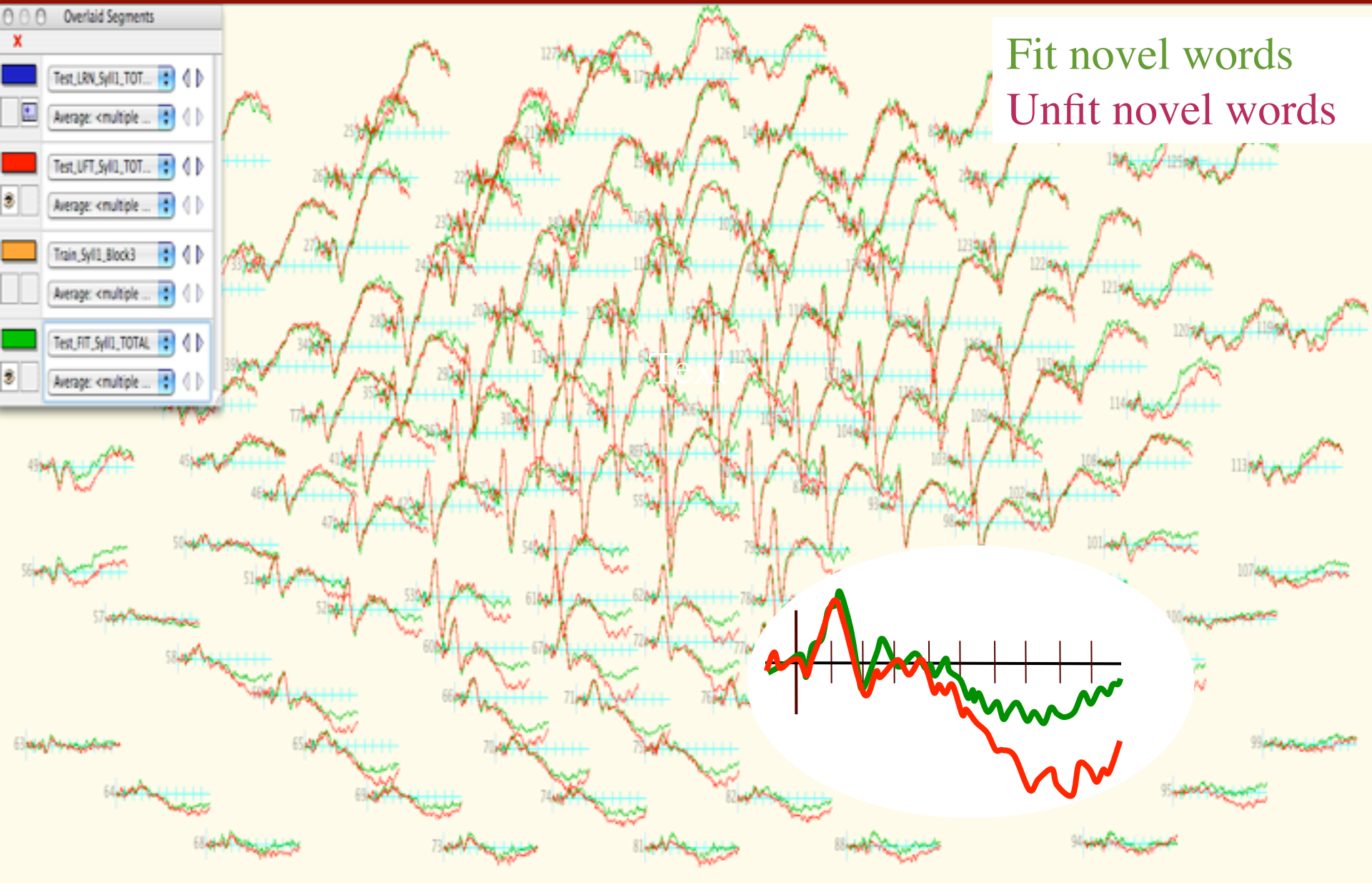
- Grandaverage ERPs time-locked to the onset of words presented during testing for all 24 subjects across all 5 testing blocks (necessary for sufficient signal-to-noise ratio for each participant)
- The onsets of Test words elicited typical auditory onset components (P1, N1, P2) over anterior/ central and medial regions
- We'll first compare the Trained words (blue) to the novel "fit" words (green)
- The novel words elicited a larger N400 at right and medial, central electrodes

Testing ERPs



- Next, Fit (green) *vs.* Unfit (red) novel words – beginning around 500 ms after word onset, Unfit words elicited a larger LPC over posterior regions
- The effect was larger for ERPs time-locked to word onsets compared to ERPs time-locked to the onsets of the 2nd syllables suggesting that the assessment of "fitness" was beginning at the onset of the word
- However, the onset of the effect around 500 ms is well after the onset of the 2nd syllable
- There was no evidence of a difference in the LPC between the Assimilation and Dissimilation conditions

Testing ERPs



Discussion

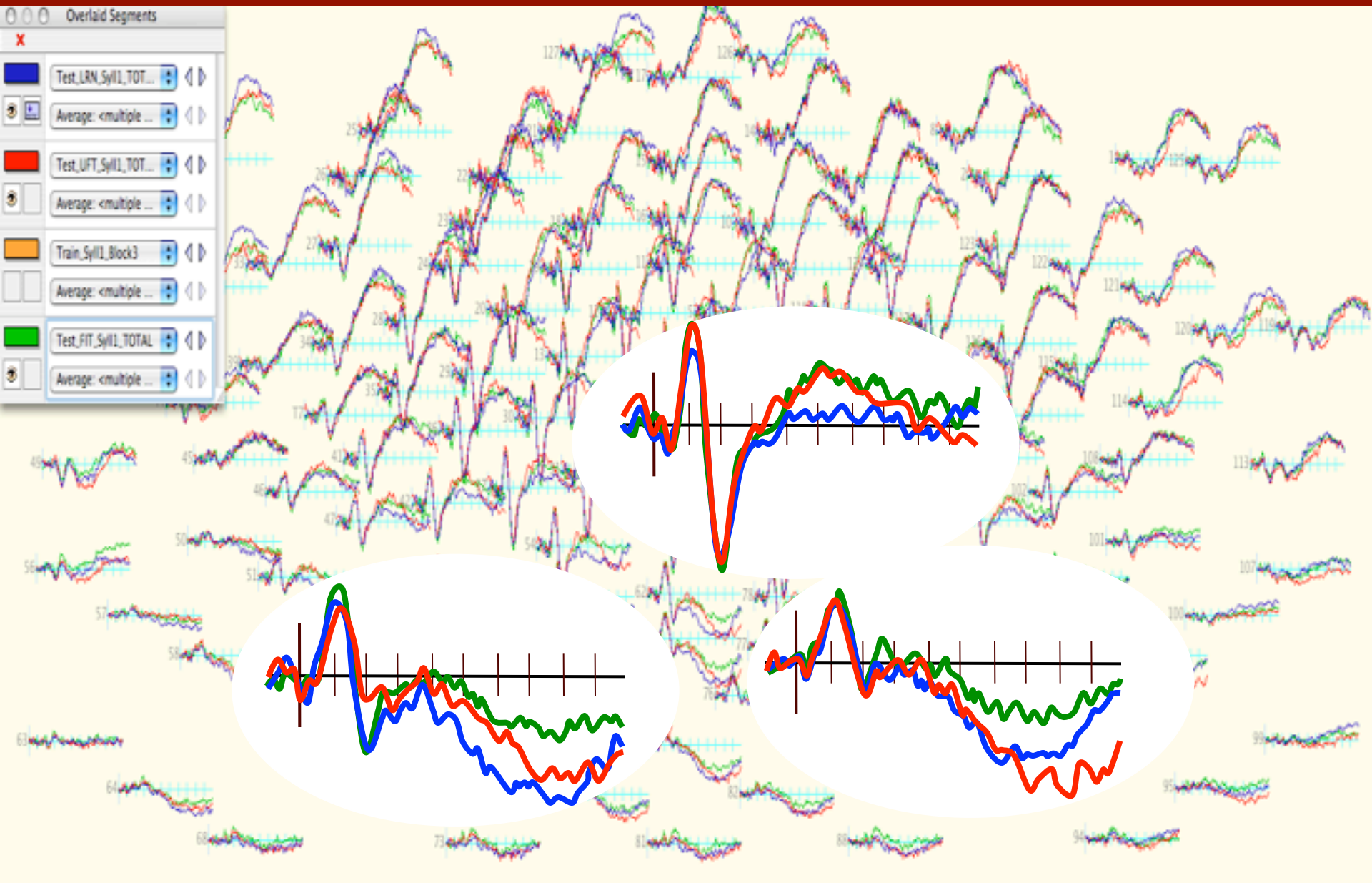
- LPC effect for violations of lab learned phonotactic pattern parallel to natural language phonotactics
  - Supports the ecological validity of at least this type of lab learning study
- We can draw a conclusion for phonological theory from the fact that these studies find an LPC, rather than an N400 effect for phonotactic violations (except in early L2 learning of Finnish VH)
  - Supports a model of phonotactics with an abstracted representation of the pattern, rather than one based only on lexical familiarity

- Future directions:
  - Are violations of different sorts of phonological regularites processed differently?
  - Are there effects of learning or behavioral task?
  - Are violations of linguistic and non-linguistic patterns processed similarly?
  - Does laboratory learning of these patterns yield similar processing across ages?

This research was supported by grant BCS-0813829 from the National Science Foundation to the University of Massachusetts Amherst, NSF Graduate Research Fellowships to Claire Moore-Cantwell and Robert Staubs and a John Merck Scholars Fellowship in Developmental Disorders to Lisa Sanders.

Thanks to Nate Olson for help running subjects, and to Elliott Moreton and many members of the UMass phonology group and the Neurocognition and Perception Lab for discussion.

Testing ERPs



- The N400 differences over right and medial, central regions show a distinction between all novel words (red and green) and the Trained words (blue)
- The distinction between Fit and Unfit are completely distinct with a positive polarity and a more posterior distribution indicating that pattern recognition and lexical familiarity are distinct processes
- The P300 effects evident for Trained compared to novel words does show some temporal and spatial overlap with the Fit/Unfit LPC, but the P300 started earlier and was more left-lateralized than the LPC

References

Breen, M., J. Kingston and L. Sanders. 2013. Perceptual representations of phonotactically illegal syllables. *Attention, Perception and Psychophysics* 75, 101-120.

Carrión, R. and B. Bly. 2008. The effects of learning on event-related potential correlates of musical expectancy. *Psychophysiology* 45, 759–775.

Dehaene-Lambertz, G., Dupoux, E., and Gout, A. 2000. Electrophysiological correlates of phonological processing: A cross-linguistic study. *Journal of Cognitive Neuroscience*, 12, 635–647.

Domahs, U., W. Kehrein, J. Knaus, R. Wiese, and M. Schlesewsky. 2009. Event-related potentials reflecting the processing of phonological constraint violations. Language and Speech 52, 415–435.

McLaughlin, J., D. Tanner, I. Pitkänen, C. Frenck-Mestre, K. Inoue, G. Valentine, and L. Osterhout. 2010. *Brain Potentials Reveal Discrete Stages of L2 Grammatical Learning. Language Learning* 60, 123-150.

Morgan-Short K,, K. Steinhauer, C. Sanz, M.T. Ullman. 2012. Explicit and implicit second language training differentially affect the achievement of native-like brain activation patterns. *Journal of Cognitive Neuroscience*. 24: 933-947.

Moreton, E. and J. Pater. 2012. Structure and substance in artificial-phonology learning. *Language and Linguistics Compass* 6 (11): 686–718.