Encoding acoustic cues in speech: Electrophysiological measurements

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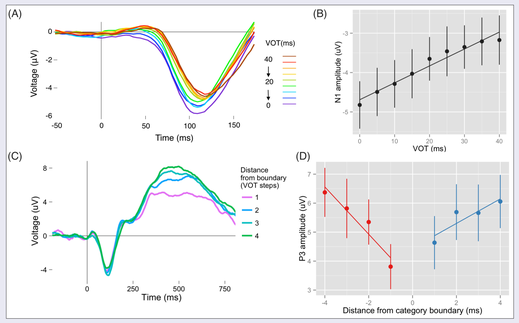
Agnes Gao[1] [ygao2@villanova.edu], Olivia Pereira[2] [opereira@villanova.edu], Joe Toscano[1] [joseph.toscano@villanova.edu]

[1] Villanova University, [2] Nemours Alfred I. duPont Hospital for Children, Nemours Biomedical Research

INTRODUCTION

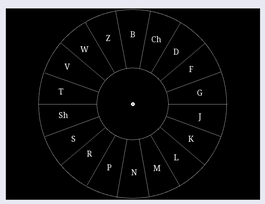
- Early work suggested fine-grained acoustic differences are discarded early in perception[1], but more recent evidence has refuted this claim[2,3]
- However, it is unclear how the perceptual system encodes specific acoustic cues at early stages
- Previous work presented an ERP approach to measure early perceptual responses,[4] examining differences along VOT continua:
  - P300 varies as a function of graded acoustic changes, relative to phoneme categories
  - Auditory N100 varies linearly with changes in VOT, suggesting a measure of early cue encoding independent of phoneme categories



- **Questions:** Does N100 serve as an index of cue encoding for other cues and phonological contrasts? What can this tell us about perceptual organization?

METHOD

- **Exp. 1:** Word-initial minimal pairs spanning 18 consonants (/b,d,g,p,t,k,f,v,s,z,ʃ,m,n,tʃ,dʒ,l,r,w/); **Exp. 2:** Naturally-produced sounds varying along VOT and release burst continua (/b,d,g,p,t,k/)
- Indicated which sound each word began with by clicking corresponding letter(s) on a display

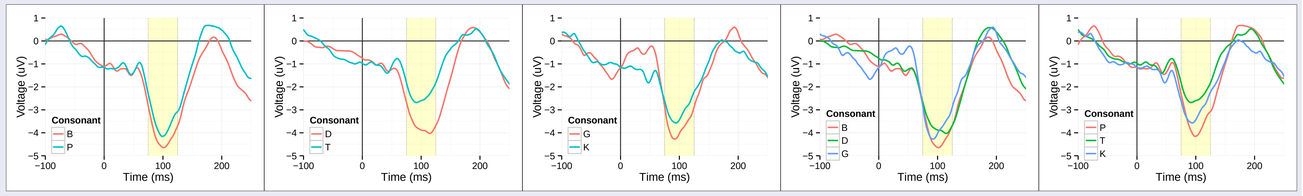


- EEG recorded using 64-ch Brain Products actiCHamp system with electrodes at standard 10-20 sites; N100 measured from average of F3, Fz, and F4
- EOG recorded via electrodes horizontal to the external canthi of each eye (horizontal) and an electrode located above the left eye (vertical); trials containing oculomotor and muscle artifacts rejected via a peak-to-peak threshold detection and visual inspection
- Electrode impedances kept at <10 kΩ; Data referenced to left mastoid online and rereferenced to average mastoids offline; EEG recorded at a sampling rate of 500 Hz; offline bandpass filtered at 0.1 to 30 Hz in ERPLAB (Butterworth filter with 12 dB/octave roll-off)

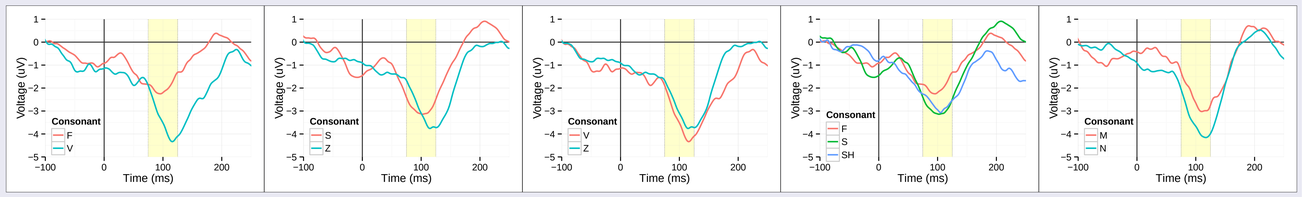
RESULTS—EXPERIMENT 1 (Natural speech)

Grand average ERP waveforms (F3,Fz,F4)

Stop consonants

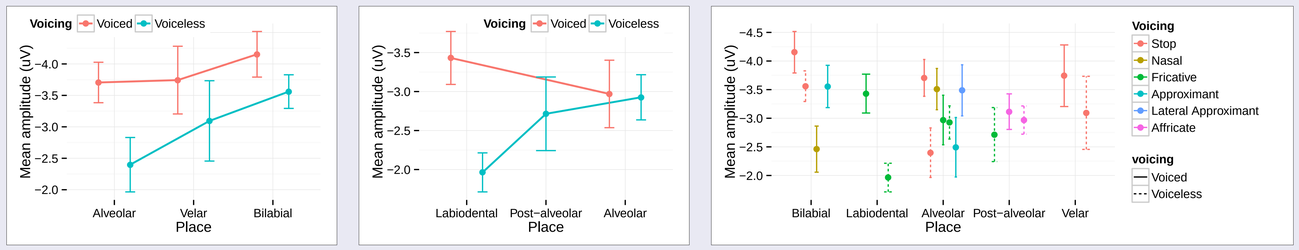


Fricatives



Nasals

Mean N100 amplitude



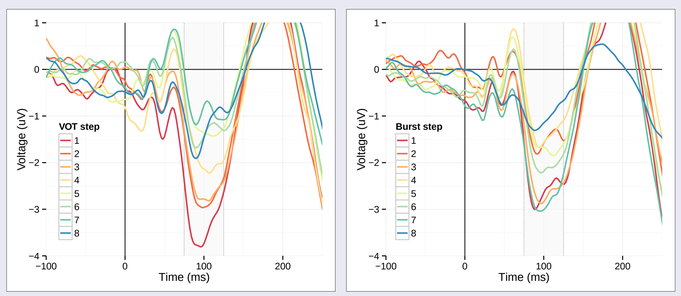
Analysis	Factor	Result
Stops	Place	$\chi^2(2)=3.7$, p=.158
Stops	Voicing	$\chi^2(1)=3.6$, p=.056
Stops	Place × Voicing	$\chi^2(1)=1.4$, p=.506

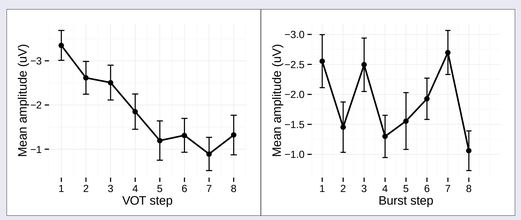
Analysis	Factor	Result
Fricatives	Place	$\chi^2(2)=.18$, p=.915
Fricatives	Voicing	$\chi^2(1)=3.7$, p=.056
Fricatives	Place × Voicing	$\chi^2(1)=5.9$, p=.015

Analysis	Factor	Result
Nasals	Place	$\chi^2(1)=6.0$, p=.015
Affricates	Voicing	$\chi^2(1)=.13$, p=.714
Approximants	Manner	$\chi^2(2)=3.9$, p=.143

RESULTS—EXPERIMENT 2 (VOT and burst continua)

Grand average ERP waveforms (F3,Fz,F4)





Analysis	Factor	Result
Stops	VOT	$\chi^2(7)=36.6$, p<.001
Stops	Burst	$\chi^2(7)=20.6$, p=.004
Stops	VOT × Burst	$\chi^2(49)=49.3$, p=.461

DISCUSSION

Experiment 1

- Differences in N100 amplitude observed for several acoustic and phonological distinctions
- Stops
  - Larger N100 for voiced than for voiceless stops
  - Replicates and extends findings from Toscano et al. (2010)[4] with different manners of articulation
  - Effects of place only observed for voiceless stops
  - Place differences do not reflect encoding based on articulation location; rather, effects appear to map onto spectral shape dimension[5] (/p/→/k/→/t/)
  - Supports N100 encoding based on acoustic cue representations, rather than articulatory-based representations
- Fricatives
  - Effect of voicing similar to stops (larger N100 for voiced consonants); suggests N100 may be sensitive to differences in low-frequency energy common to voicing distinctions across manner of articulation
  - Place × voicing interaction driven by voicing effect for /f,v/
- Nasals
  - Larger N100 for /n/ (alveolar) than for /m/ (bilabial); similar to the place effect for fricatives, and different from direction of place effect for stops

Experiment 2

- Linear effect across VOT continuum, replicating previous work[4]
- Effect of release burst continuum, but non-linear pattern across continuum
- Suggests listeners may not be encoding overall burst spectrum shape, but a more specific cue in the burst (e.g., mean frequency)

Conclusions: The N100 can serve as a useful tool for studying cue encoding at early stages of speech perception across a range of phonological distinctions

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- **References:**

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