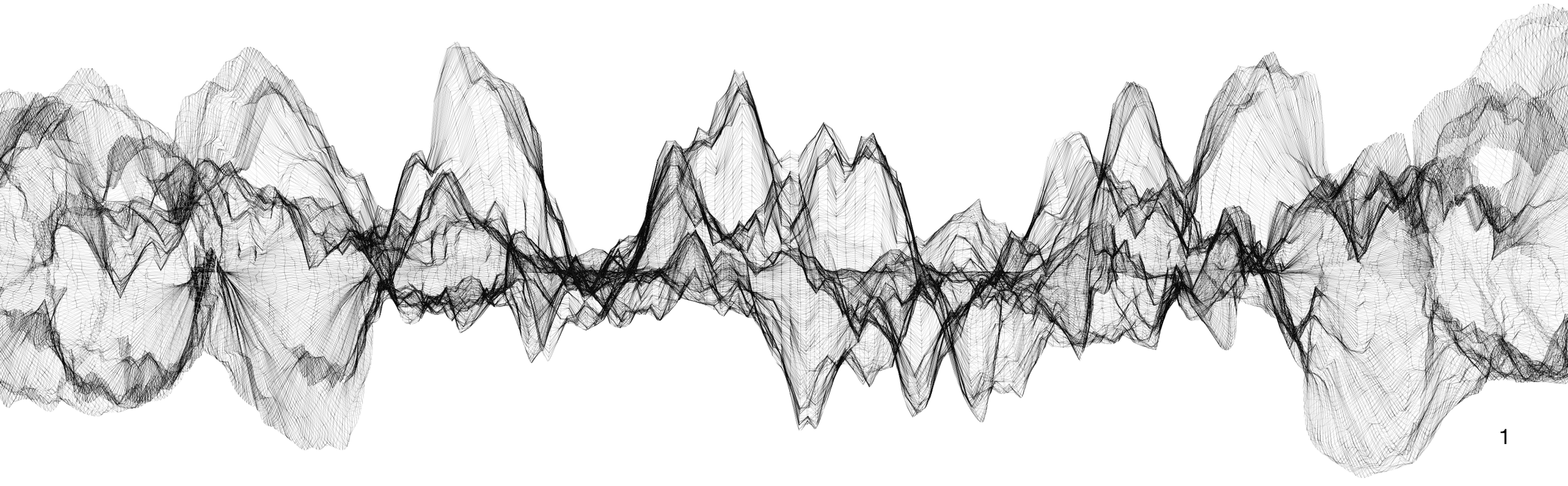
NEW YORK UNIVERSITY

Phonological (un)certainty weights lexical activation

Laura Gwilliams, David Poeppel, Alec Marantz & Tal Linzen

7th January 2018



ballet

blind

big

bath

baptist

bond

band

ballot

book

b

break

band

bind

black

boast

balance

back

based on the **Cohort model** of spoken word recognition: Marslen-Wilson, 1978

ballet

bath

band

baptist

ballot

b a

band

balance

back

based on the **Cohort model** of spoken word recognition: Marslen-Wilson, 1978

ballet

ballot

b a l

balance

based on the **Cohort model** of spoken word recognition: Marslen-Wilson, 1978

ballot

b a l ə

balance

based on the **Cohort model** of spoken word recognition: Marslen-Wilson, 1978

b a l ə n

balance

based on the **Cohort model** of spoken word recognition: Marslen-Wilson, 1978

But what about ambiguity?

- Real world speech is **noisy and ambiguous**; there is not a direct mapping between speech and phonemes

b b b p p

ballet

prove

pin

bath

pacify

bond

palate

beef

book

p

pants

balance

bind

paddle

boast

poke

panda

ballet

prove

pin

bath

pacify

bond

palate

beef

book

b p

b p

pants

balance

bind

paddle

boast

poke

panda

ballet

prove

pin

bath

pacify

bond

palate

beef

book

b

pants

balance

bind

paddle

boast

poke

panda

ballet

prove

pin

bath

pacify

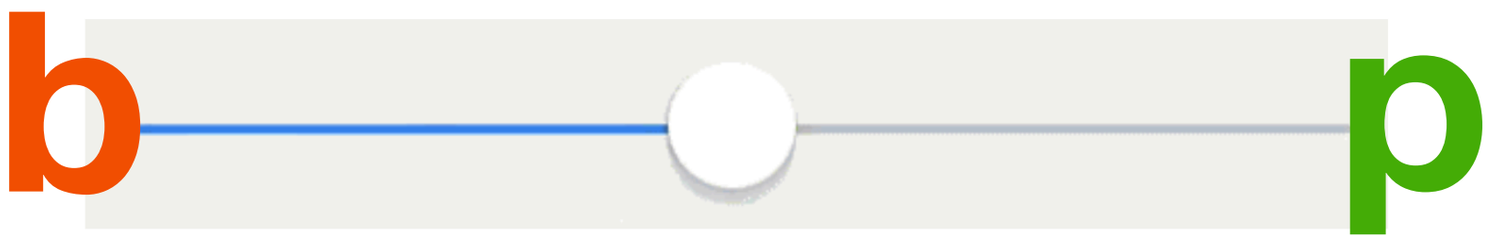
bond

palate

beef

book

b



pants

balance

bind

paddle

boast

poke

panda

ballet

bath

pacify

palate

p a

pants

balance

paddle

panda

ballet

palate

þ a l

balance

palate

þ a l ə

balance

þalən

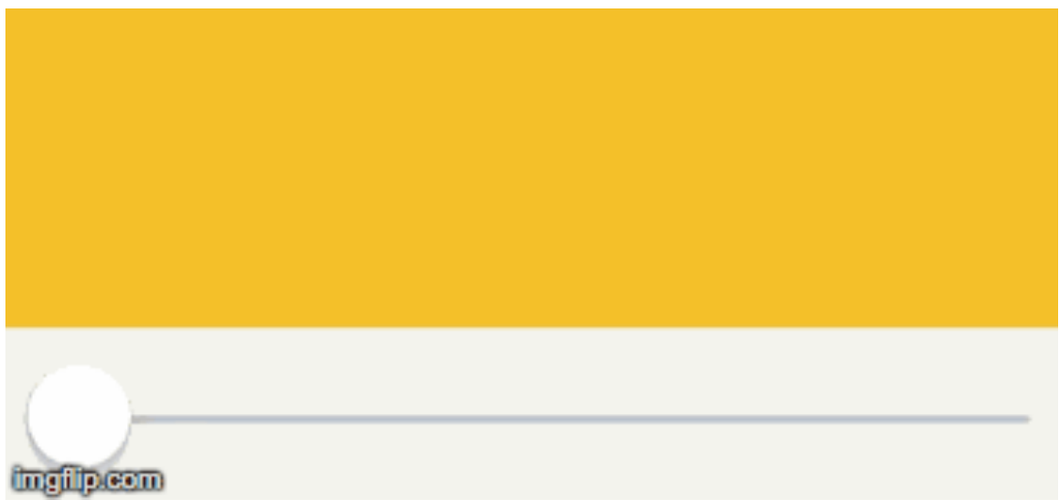
balance

Two Computational Models

$$P(\varphi_a|A)$$

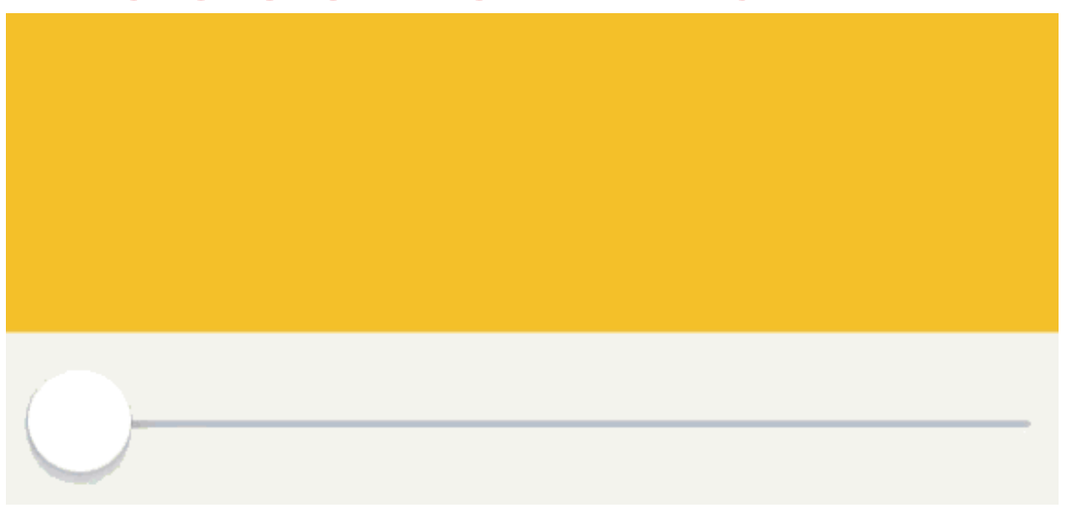
φa = phoneme$_a$ A = acoustic input

SWITCH-BASED



- 1 cohort of words
- binary acoustic term

ACOUSTIC WEIGHTED



- 1+ cohort of words
- continuous acoustic term

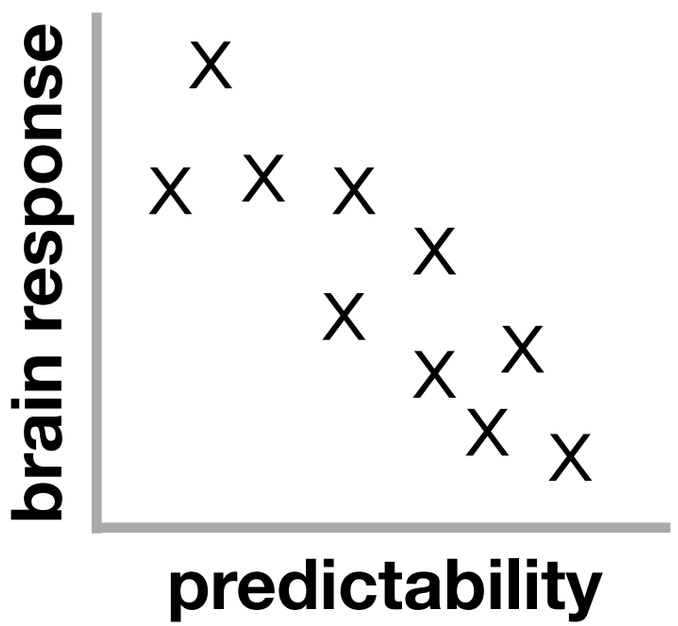
Research Question

Does acoustic-phonetic uncertainty weight activation at the lexical level?

Prediction aids speech comprehension

- The brain **predicts future linguistic content** in terms of phonemes, morphemes, words and syntactic structures

- When input is **predictable**, it is easier to process; reflected as a relative **reduction in neural amplitude**



Quantifying predictability

- **Surprisal**:

Probability of an outcome

$$-log_2 \frac{f(\varphi_1, \ldots, \varphi_t)}{f(\varphi_1, \ldots, \varphi_{t-1})}$$

- **Entropy:**

Uncertainty over future input

$$-\sum_{w \in C} P(w|C) log_2 P(w|C)$$

Critical Variables

- **Surprisal**:

Switch-based
Acoustic-weighted

$$-log_2\left(P(\varphi_a|A)\frac{f(\varphi_a,\varphi_2,\ldots,\varphi_t)}{f(\varphi_a,\varphi_2,\ldots,\varphi_{t-1})}Q_a^t + P(\varphi_b|A)\frac{f(\varphi_b,\varphi_2,\ldots,\varphi_t)}{f(\varphi_b,\varphi_2,\ldots,\varphi_{t-1})}Q_b^t\right)$$

- **Entropy:**

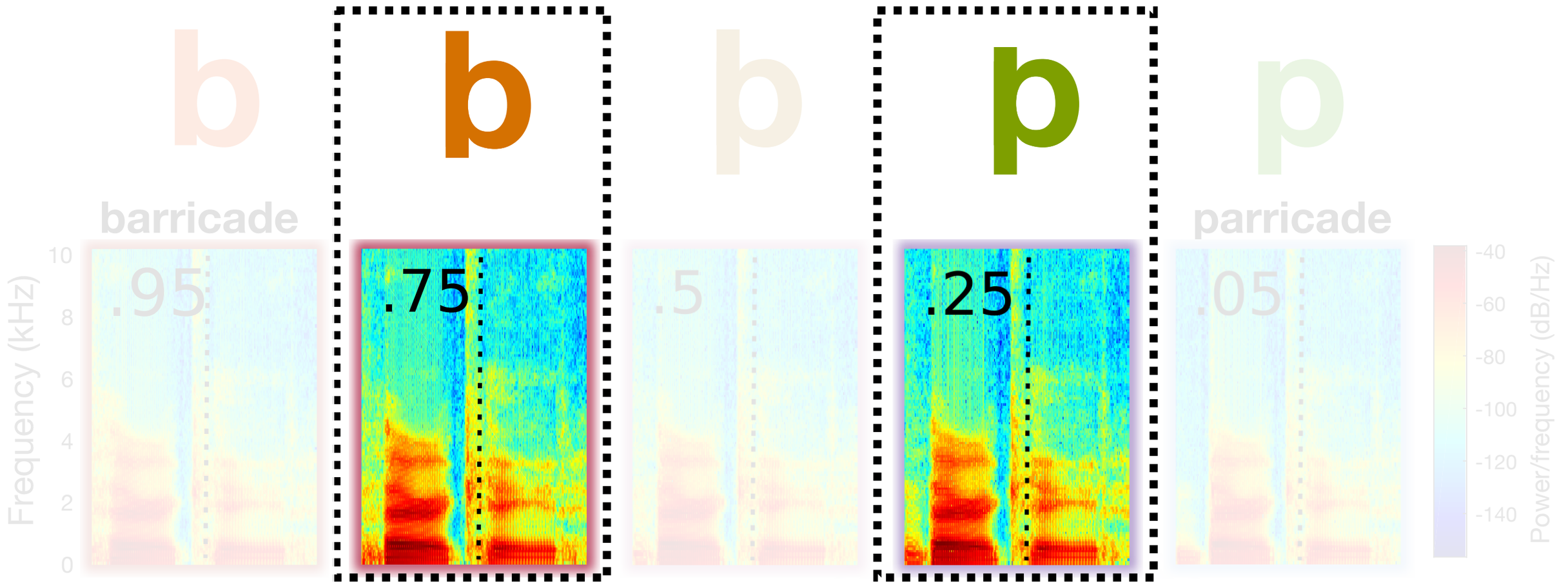
Switch-based
Acoustic-weighted

$$P(w|C,A) = P(w|C_a)P(\varphi_a|A) + P(w|C_b)P(\varphi_b|A)$$

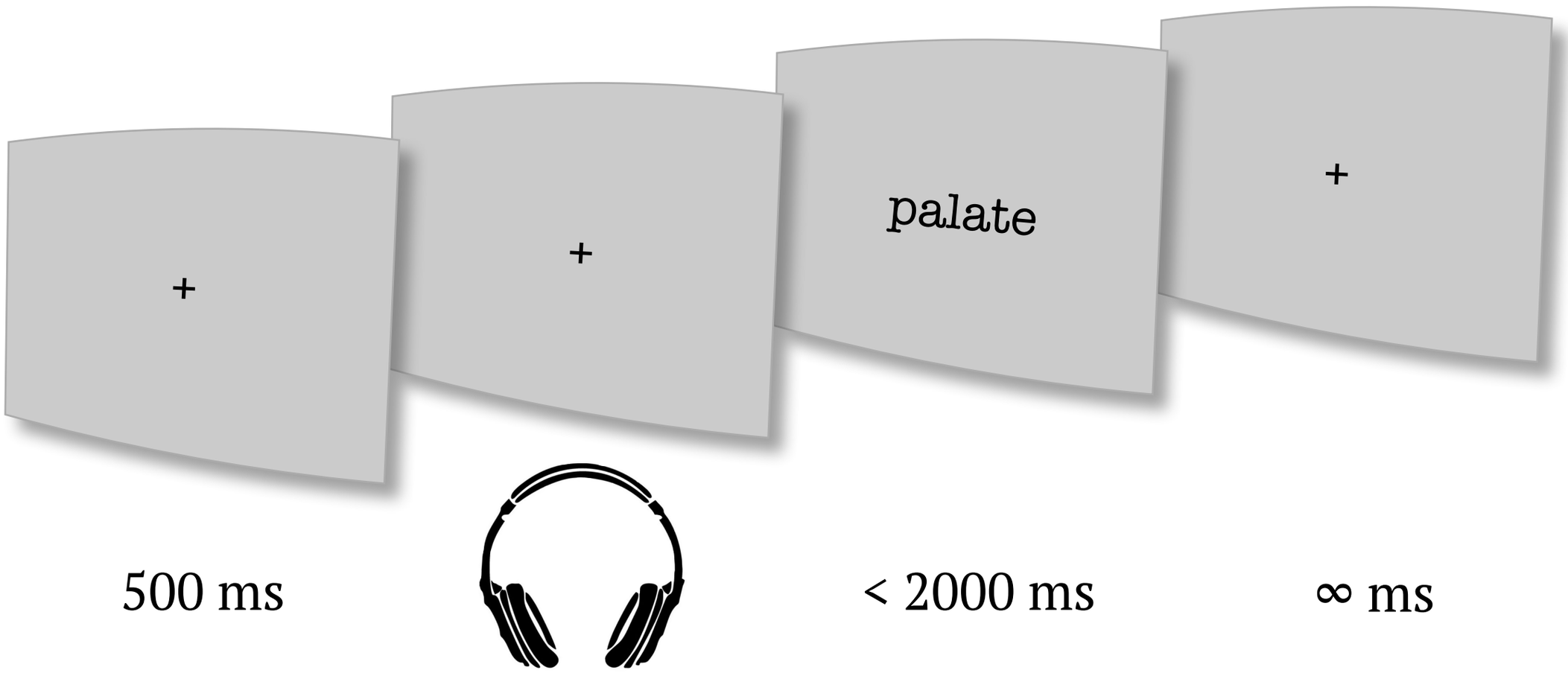
Stimuli

Acoustic weighted: $P(\varphi_a|A) = .75$ $P(\varphi_a|A) = .25$

Switch-based: $P(\varphi_a|A) = 1$ $P(\varphi_a|A) = 0$



Protocol



Procedure & Analysis

x 25

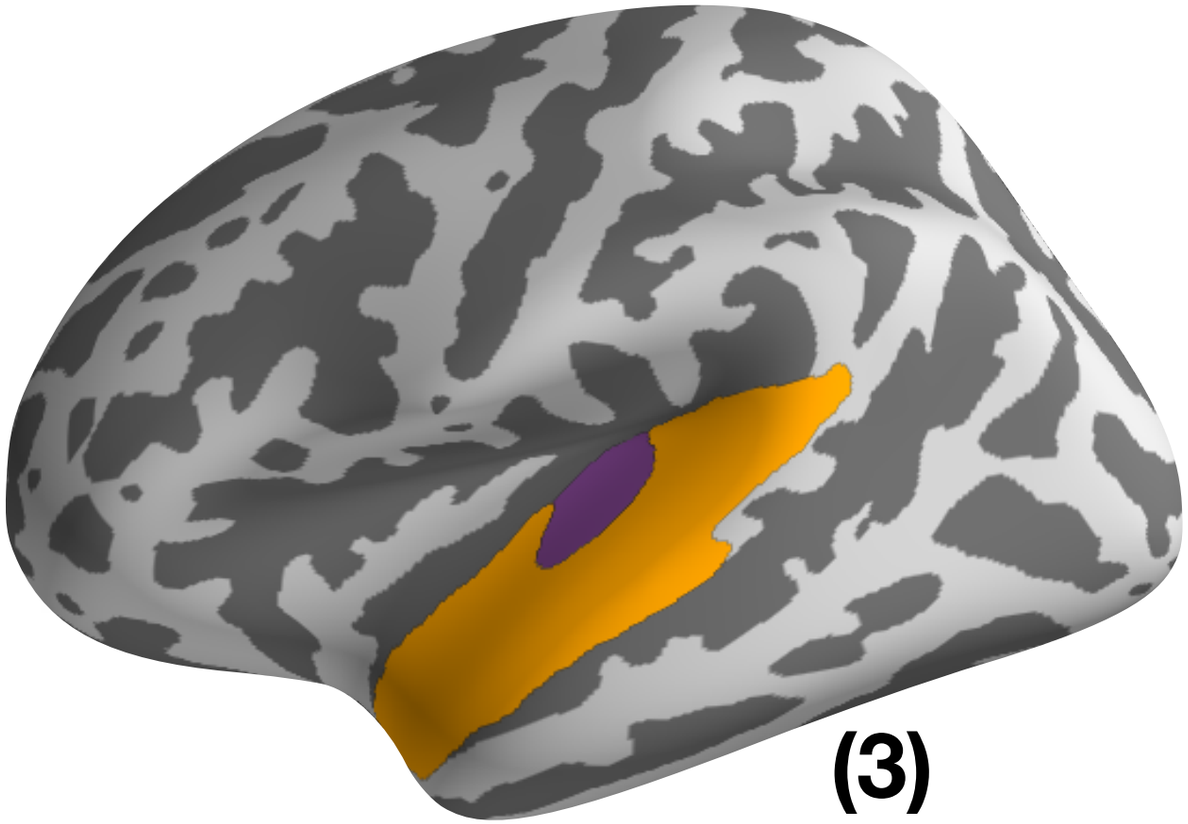
(1)

208 sensors

time (ms)

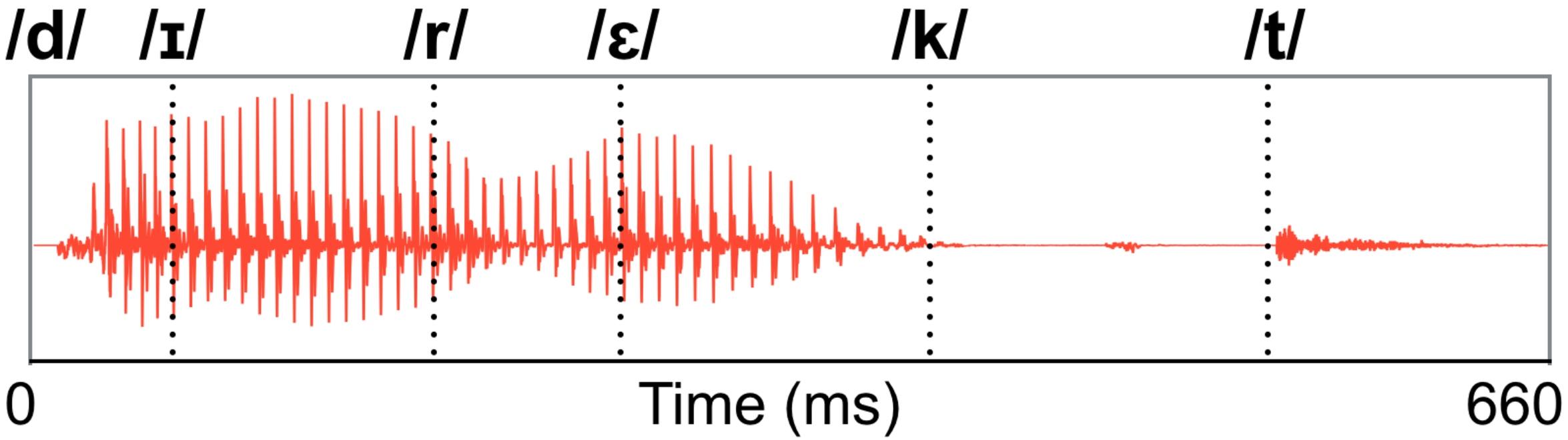
(2)

averaged 200:250 ms



(3)

Procedure & Analysis



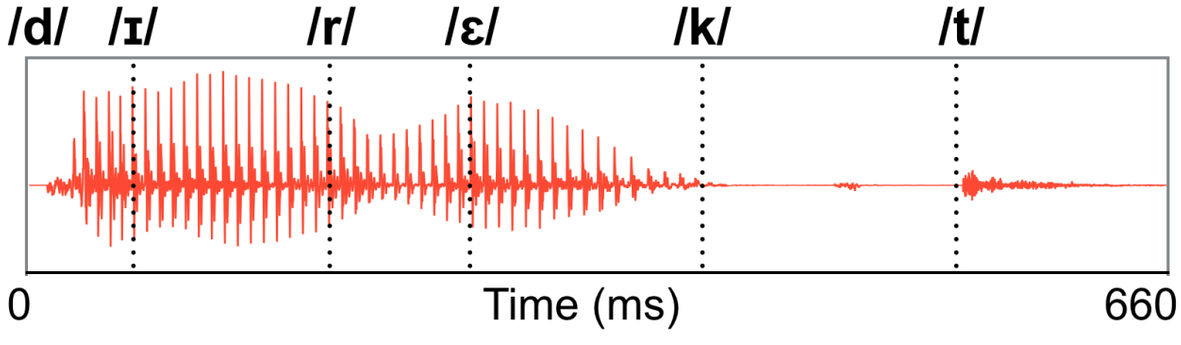
Model Setup

- **Critical variables**:

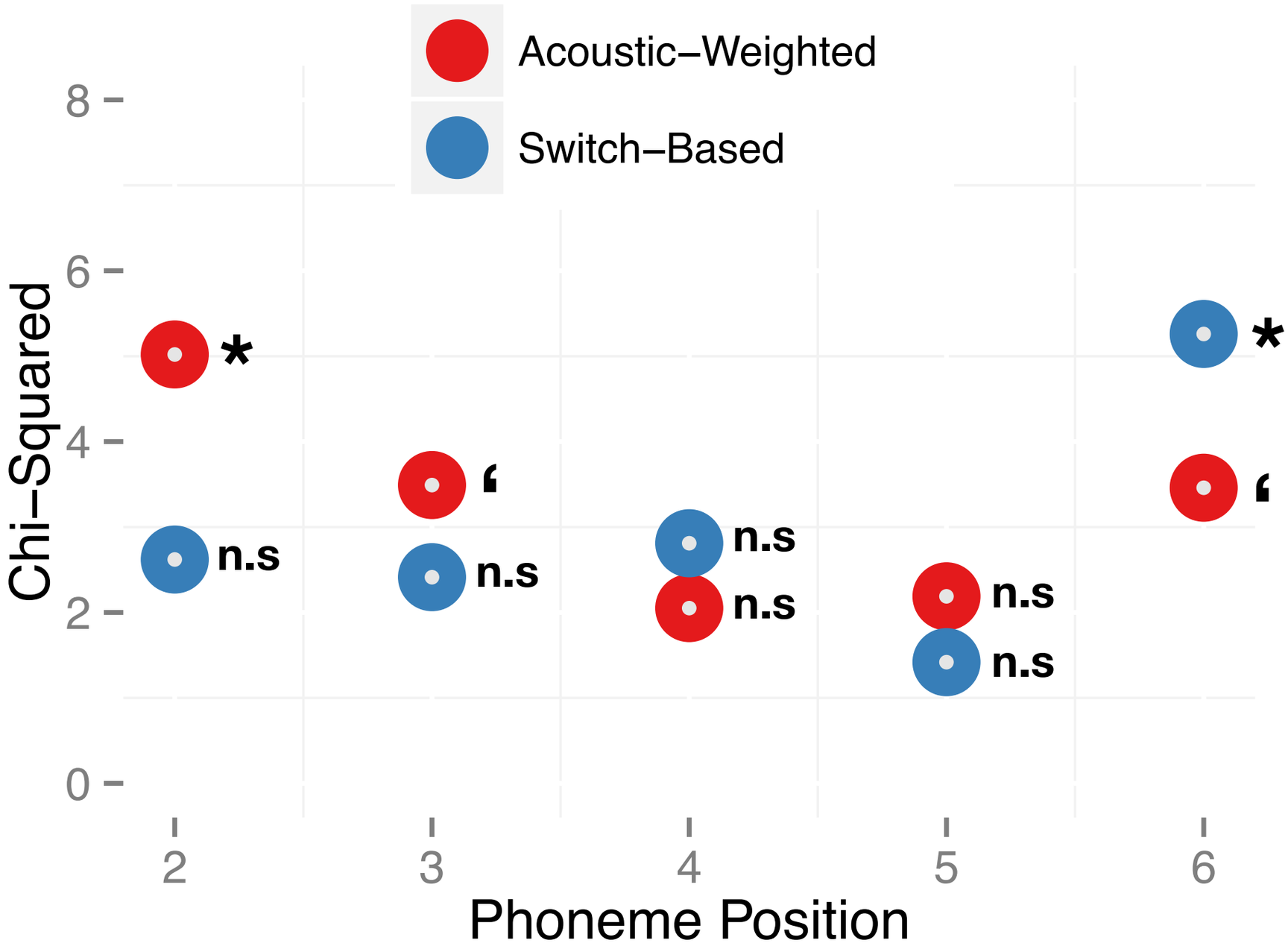
acoustic-weighted entropy
acoustic-weighted surprisal
switch-based entropy
switch-based surprisal

- **Control variables**:

phoneme latency (ms)
phoneme latency (number of phonemes)
trial number
block number
stimulus amplitude
phoneme pair
ambiguity

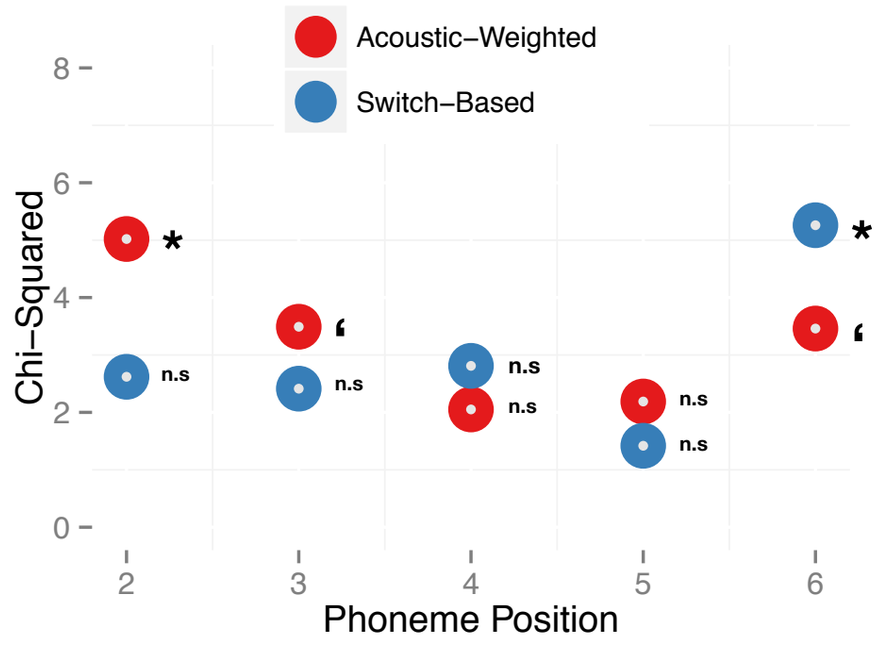


Results


Acoustic–Weighted
Switch–Based
8
6
4
2
0
Chi–Squared
*
*
n.s
n.s
n.s
n.s
n.s
n.s
2
3
4
5
6
Phoneme Position

Discussion

- Fine-grained acoustic information does weight lexical candidates
- There is a **dynamic interaction** between different levels of linguistic description: phonological <-> lexical
- Not a single heuristic applied in all situations: perhaps reflects that the **brain commits to an interpretation** of the phonological category after a certain period of time

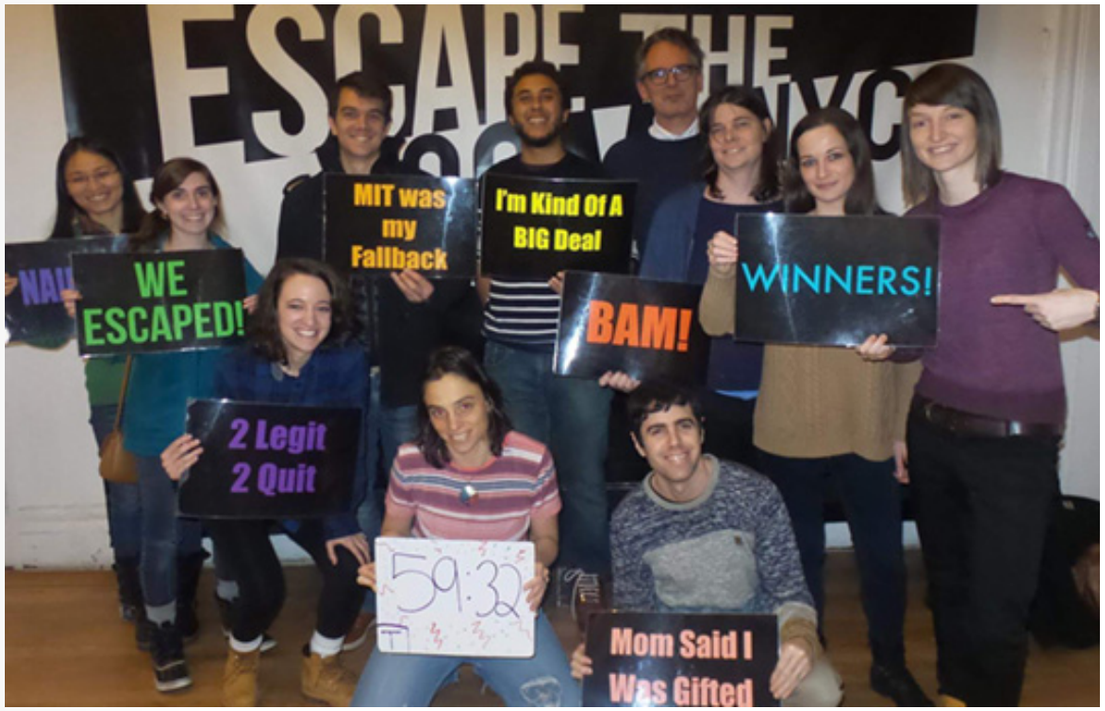


Acoustic-phonetic uncertainty can weight activation at the lexical level

laura.gwilliams@nyu.edu
@GwilliamsL

With big thanks to:

- My supervisors, **Alec Marantz** and **David Poeppel**, as well as everyone in the **Neuroscience of Language Lab** and **Poeppel Lab**!



Funding: G1001 Abu Dhabi Institute