Towards A Domain-General Theory of Phonological Contrast

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Cornell
Ithaca, NY (Virtually)

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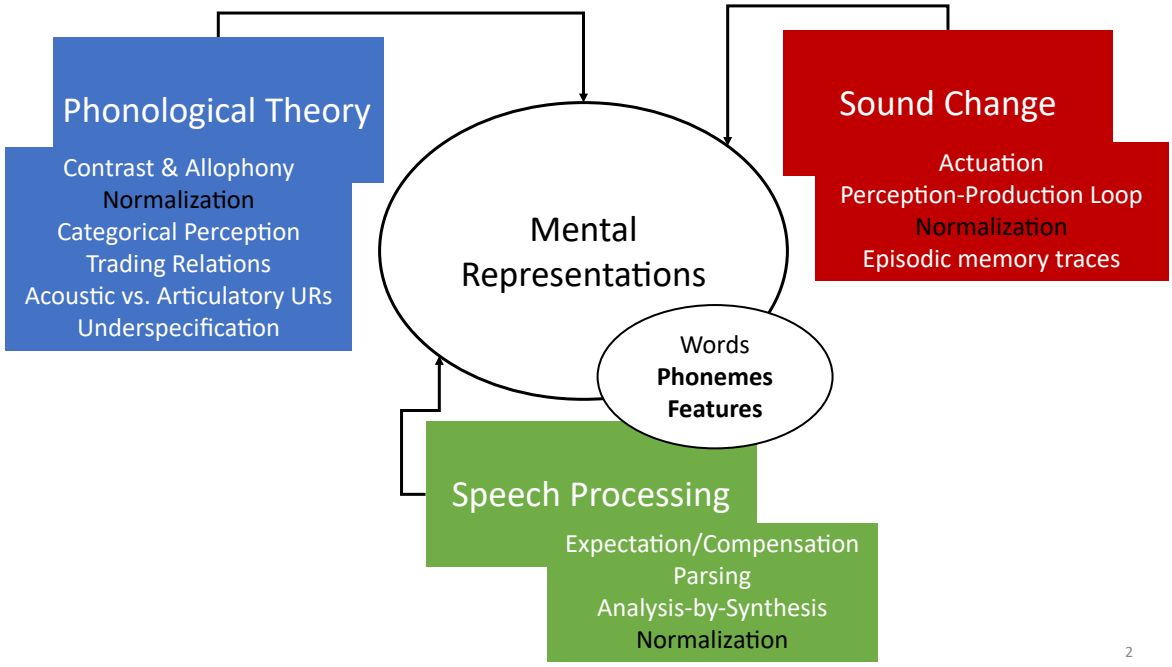

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Phonological Theory

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Contrast

The Classical Model:

Words	Phonemes	Features
"bit" vs. "bead"	Non-minimal contrast	
"bit" vs. "bid"	/t/ vs /d/	[+coronal, +obstruent, -sonorant, -voice, ., ., .] [+coronal, +obstruent, -sonorant, +voice, ., ., .]
"spit" vs. "sbit"	Lack of contrast	

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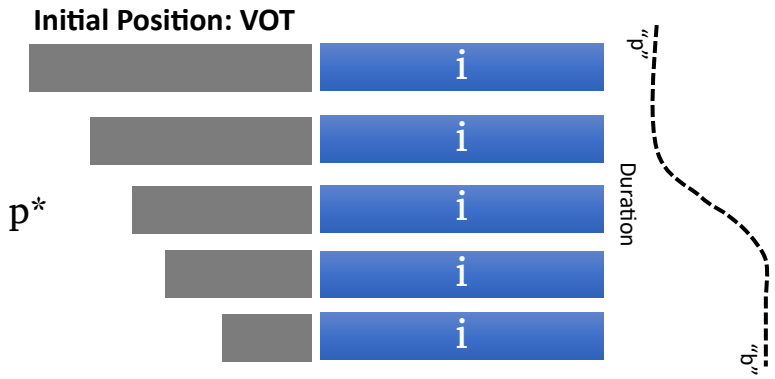
Diagnostics of Contrast

Word Recognition	Phoneme Recognition: Categorical Perception Experiment

"pea" vs. "bee"



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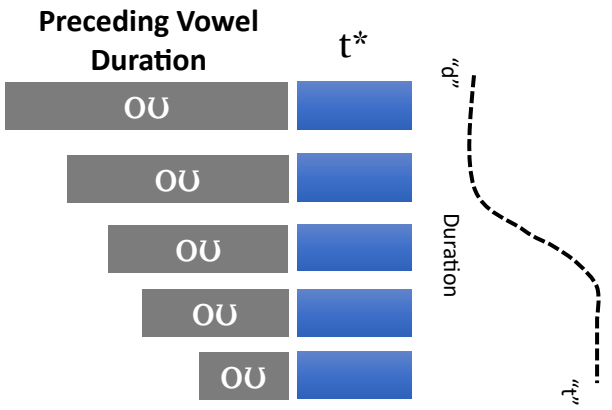
Diagnostics of Contrast

Word Recognition	Phoneme Recognition: Categorical Perception Experiment

"coat" vs. "code"



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Allophony

What is the underlying contrastive feature?

- /p/→[pʰ]/ˈ__V
- /b/→[p]/#__

pat/bat:
/p/ has longer VOT than /b/, word-initially

- /p/→[b]/ˈV__V
- /b/→[p]/__#
- /p/→[p̚]/__#

rapid/rabid:
/p/ has longer closure duration than /b/, post-stress, word medially

tap/tab:
Vowel preceding /b/ is longer than vowel preceding /p/, in coda position

/b/ ≠ [b]

/χ/ ≠ [b]

Paradox 1:
phonetic symbol system is identical to phonological symbol system

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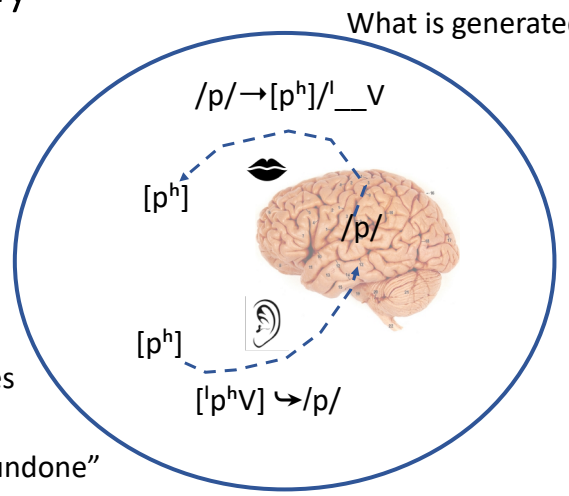
Allophony



Allophony implies normalization

That has to be "undone"

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Trading Relations

The (lack of) invariance problem

- Longer VOT changes category membership

- shorter following vowel shifts category boundary to shorter stop

Summerfield (1981); Miller & Volaitis (1982)

- longer preceding vowel shifts category boundary to longer stop

Summerfield (1981); Miller & Volaitis (1982)

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Cues that could be exploited by listeners

Word-Final stops:

- duration of voicing
- intensity of voicing
- Aspiration
- F0 contour
- length of vowel formant transitions with respect to steady state duration
- F1 offset frequency
- speed of jaw lowering
- jaw offset position

Continuous "trade offs"

…/acoustic/articulatory/phonetic/ phonological/…

But why does allophony occur in the first place?

Paradox 2:
Contrast should prevent allophony!

Fitch 1981; Crowther & Mann 1992; Van Summers 1987
cf. Bailey & Summerfield 1980

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Specification and Underspecification

Variation is allowed on dimensions that are not specified

Control of articulation is evidence for specification

[±voice]

[voice]

or not

Ø

- aspirated/un-aspirated
- long VOT/short VOT
- Released/un-released
- voiced/voiceless/ partially voiced

voicing present

voicing present when context is appropriate

p#d

VpV

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What are the Underlying Features?

Articulatory rather than acoustic?

Fitch 1981; Crowther & Mann 1992; Van Summers 1987; Bailey & Summerfield 1980

English:
[spread glottis] vs. Ø
("p" vs. "b")
Kim 1970; Iverson & Salmons 1995

Russian:
[voice] vs. Ø
("b" vs. "p")
Keating 1984; Beckman et al 2013

Specifications are not necessarily parsimonious in real human languages

Regressive assimilation to
s
al 1992;Jansen 2004

g of passive voicing
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n:
[spread glottis] vs. [voice]
Beckman et al 2001

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Important Implications: [wake up here]

- Categorical perception does not entail a *necessarily* contrastive feature, only a possible one (when all other information is absent). See Trading Relations.
- There is a very large number of possible allophonic rules (at least on the acoustic side).
- Allophonic rules imply normalization
- The relationship between underspecification and variation implies an inverse relationship between contrast and allophony
- Specification is likely to be continuous, and not necessarily parsimonious [this is an empirical question]

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Sound Change

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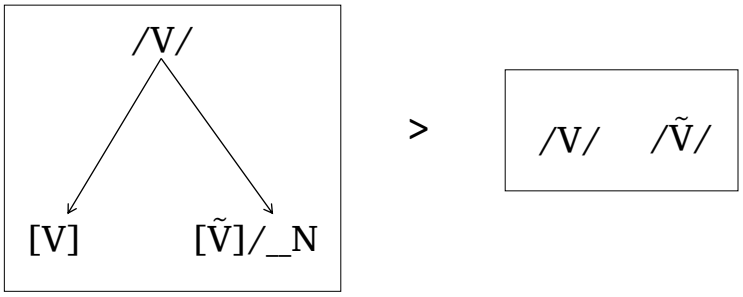
The Actuation Paradox

Paradox 3

A direct result of the normalization assumption



Normalization: No Change

Lack of Normalization: Change

In collusion with the discrete sequencing assumption k+æ+t

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The Actuation Paradox

Allophonic Vowel Nasalization Rule [synchronic]:

$V \rightarrow \tilde{V} / \_N$

Loss of coda nasals [diachronic]:

$N > \varnothing / \_.$

Loss of allophonic rule/predictability [synchronic]

$V \rightarrow \tilde{V} / \_??$

$V \rightarrow V / \_??$

Paradox 3:
loss of allophonic context
should lead to
loss of allophone

Minimal Pair Test

/V/ vs. /Ṽ/

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Models of Sound Change

Phonetically ambiguous/outlier tokens are discarded

- As a result of competing contrastive categories
  (Blevins & Wedel 2009;Wedel 2006, 2007; Tupper 2014)
- In speech mode, but not non-speech mode
  (Garrett & Johnson 2013)
- For some (neurotypical) individuals, but not others
  (Yu 2013)
- Except when misparsing occurs
  (Kirby 2014)

Sometimes you normalize
Sometimes you don't

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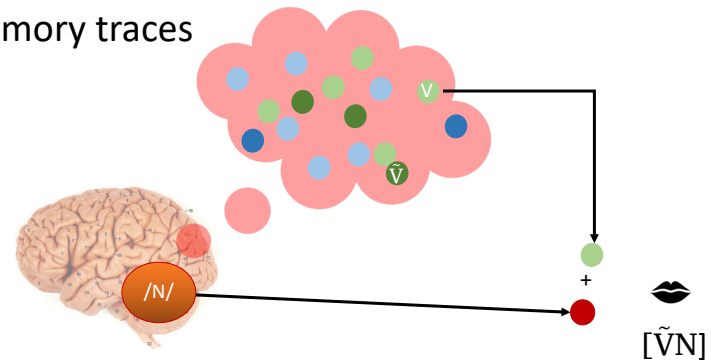
No Normalization = Change?

Exemplars: episodic memory traces

Paradox 4: unnormalized tokens are not consistent with allophonic rules



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No Normalization = Change?

Exemplars: episodic memory traces

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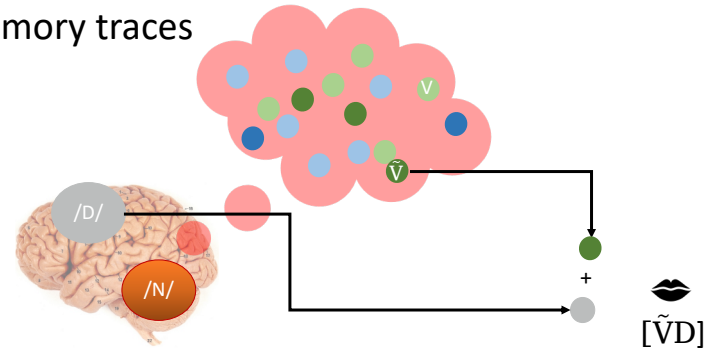

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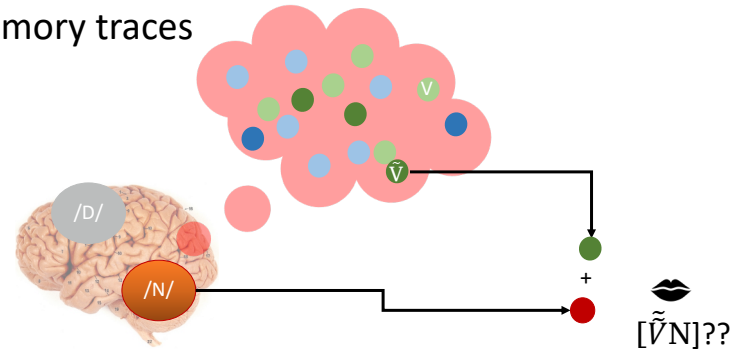
No Normalization = Change?

Exemplars: episodic memory traces

Paradox 4: unnormalized tokens are not consistent with allophonic rules

Paradox 5: the same symbol systems are used for acoustic and articulatory representations!



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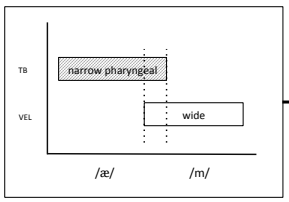
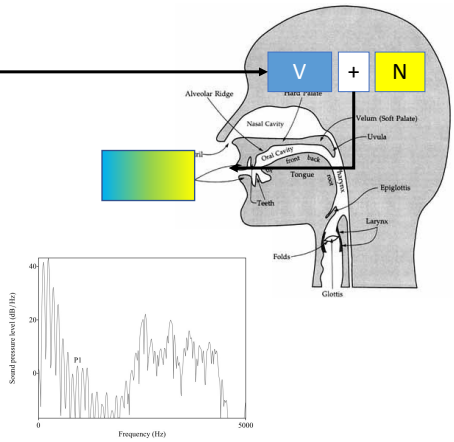
Why do allophones exist?

Coarticulation!



Browman & Goldstein 1988



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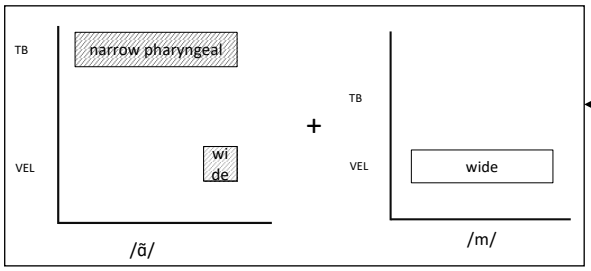

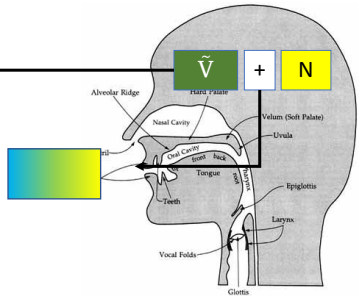

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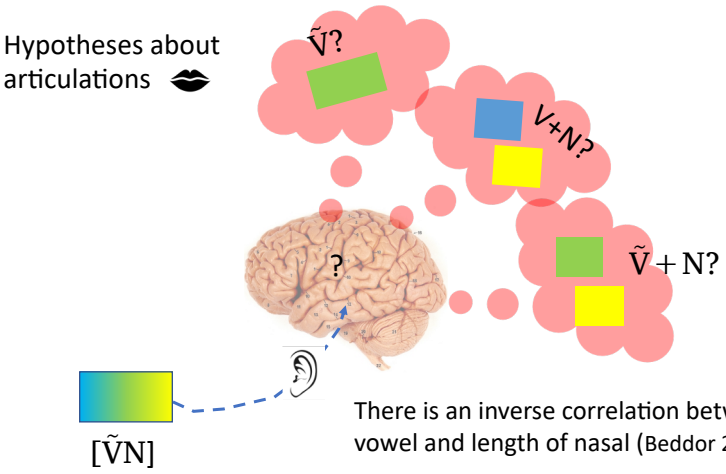
Perception ⇔ Production



Model (Morley 2019):

- Ambiguity in normal speech processing
- Competing Hypotheses (Parses) for each acoustic input
- Parse depends on acoustic variables
- Not nasal loss, but nasal merger

There is an inverse correlation between degree of nasalization on vowel and length of nasal (Beddor 2013).

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Important Implications: [wake up here]

- Speech perception must involve:
  - mapping acoustic input to articulatory categories (targets)
  - Segmentation of ambiguous input
- Lack of normalization implies lack of allophony
- Unless allophony is an emergent property of articulation
- Incremental change is possible with distributions of stored, unnormalized acoustic tokens (exemplars)

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Speech Processing

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Is Normalization Required?

1. Longer vowel creates expectation for following voiced (rather than voiceless) stop:

oʊ

Sounds like "coat"

oʊ

Sounds like "code"

2. Nasalized vowel spliced into non-nasal syllable sounds more like lower vowel (higher F1): Krakow et al 1988

sɛ̃nd → /ɛ/

sɛ̃nd / sɛd → s ɛ̃ d → /æ/

3. Expected degree (and direction) of place-of-articulation assimilation facilitates word recognition: Gow and McMurray 2007

gɹin bin , gɹin dɔg >> gɹi n dɔg , gɹi n bin

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Is Normalization Required?

Acoustic Normalization:

- attributing distributed acoustic cues to individual (source) segments
- adjusting acoustic cue values based on context

[sɛ̃nd] ↬/ɛ/

oʊ d ↬ /oʊ/

gɹinʷ bin ↬ /n/

Implies a more abstract/invariant underlying representation that must be closely matched

e.g., Gow (2002); Beddor et al. (2002); Kirby (2014); McMurray et al (2011)

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Is Normalization Required?

- Trading Relations/Categorical Perception/(In)Variance Problem
- Expectation/Compensation/Prediction
  - No acoustic cues are absolute
  - Classification depends strongly on other cues present, context
  - Previous input, current context, current knowledge generate predictions about upcoming material
  - listeners are highly sensitive to correlations among acoustic cues

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The Phonological Parser

Vowel Silence Frication

gɹ eɪ ∫ ɪp "gray ship"

gɹ eɪ ∫ ɪp "great ship" Lengthen silence

gɹ eɪ ∫ ɪp "gray chip" Shorten frication noise

gɹ eɪ ∫ ɪp "great chip" Lengthen silence again

Repp et al. (1978)

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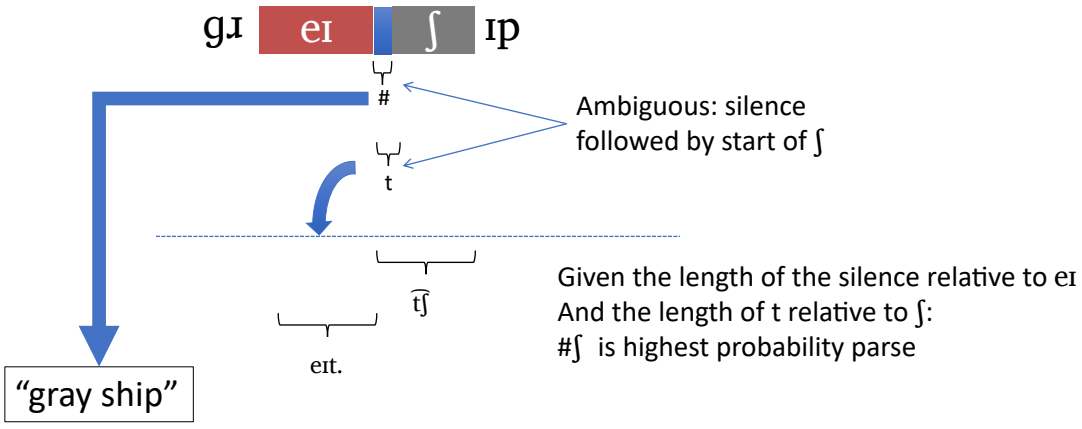
The Phonological Parser



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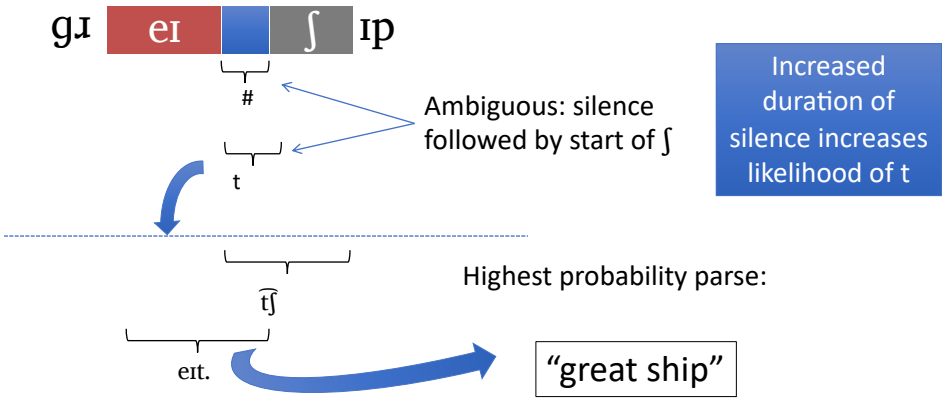
The Phonological Parser



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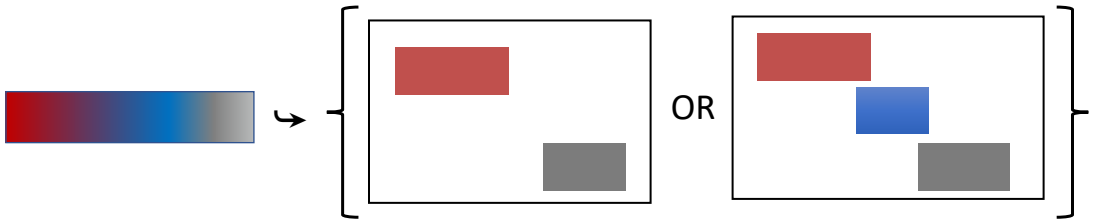
Is Normalization Required?

Rather than matching abstract acoustic symbols,

speech perception can be described as choosing the optimal phonological parse, that is,

the likeliest string of **articulatory symbols** that would result in the observed acoustic input

Remember Paradox 5!



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Is Normalization Required?

Rather than matching abstract acoustic symbols,

speech perception can be described as choosing the optimal phonological parse, based on:

- All available contextual information
- Self-consistency

Local Optimum

- Relative feature values

- In most cases, from a small candidate set (~ 2 words)
- In most cases, involving local comparisons within a 2-3 segment window

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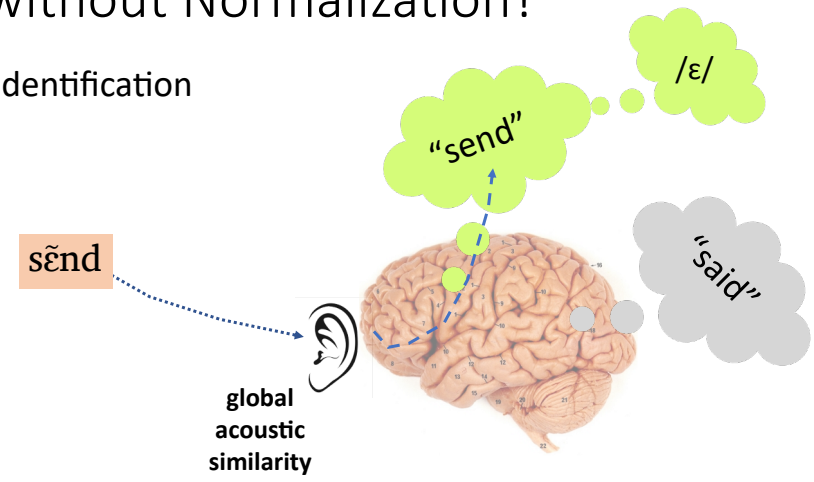
A World without Normalization?

Classification/Identification

Word-level



Krakow et al. 1988

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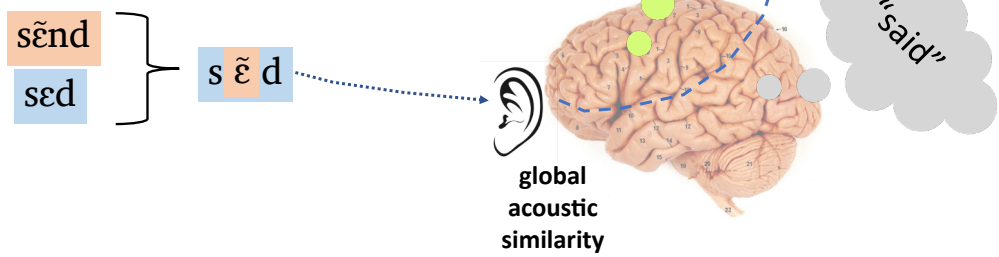
A World without Normalization?

Classification/Identification

Word-level



Krakow et al. 1988

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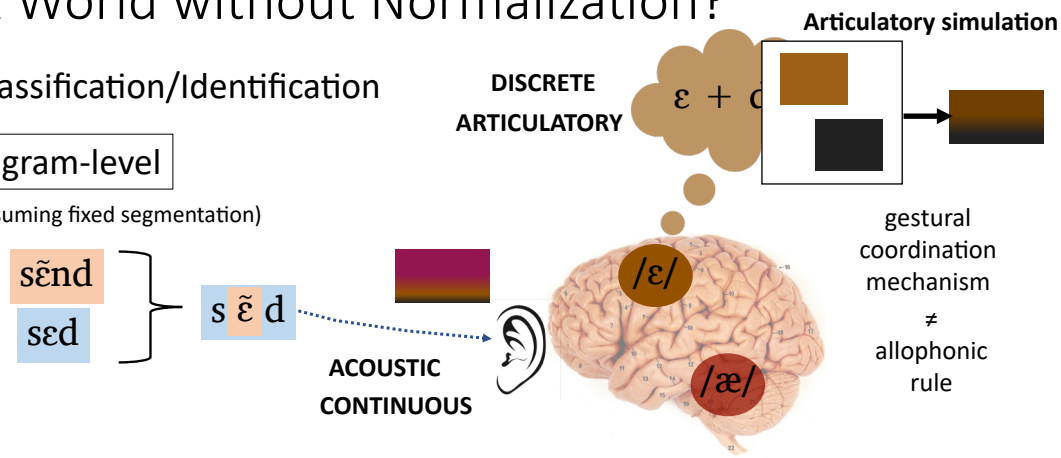
A World without Normalization?

Classification/Identification

Bigram-level

(assuming fixed segmentation)



Analysis-By-Synthesis: Halle & Stevens (1967); Poeppel & Monahan (2011)

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A World without Normalization?

Classification/Identification

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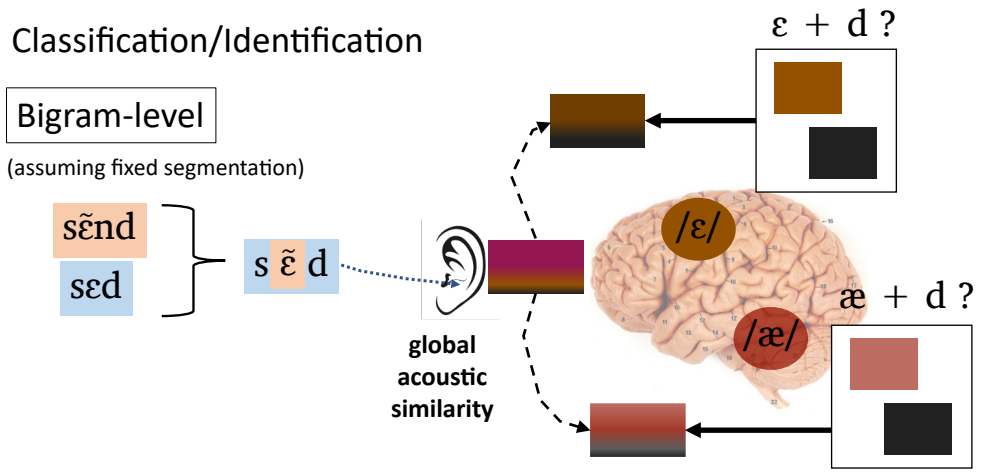

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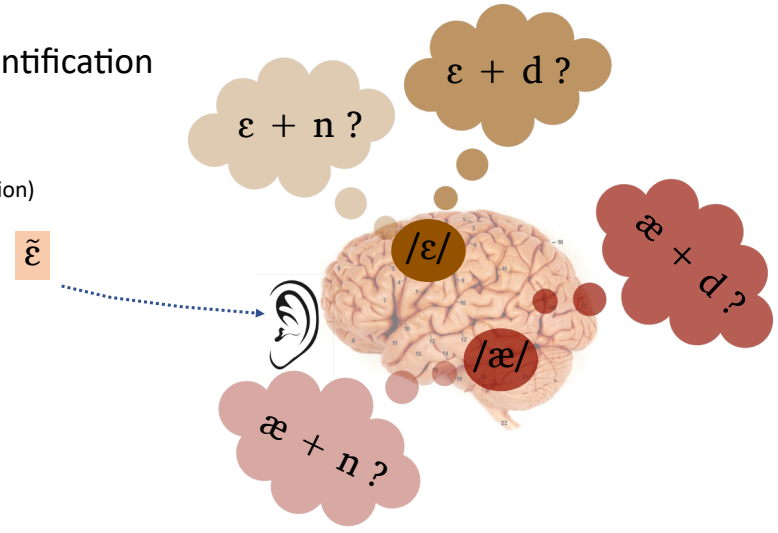
A World without Normalization?

Classification/Identification

Phoneme-level

(assuming fixed segmentation)



Krakow et al. 1988

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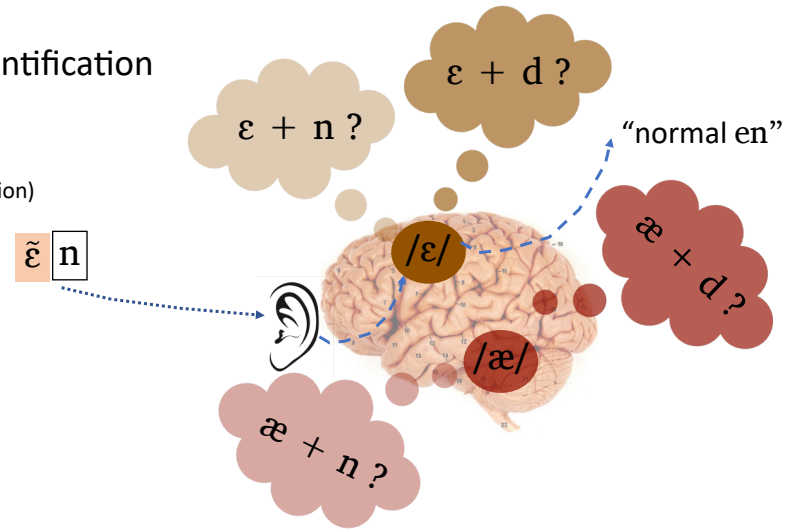
A World without Normalization?

Classification/Identification

Phoneme-level

(assuming fixed segmentation)

ɛ̃ n



Krakow et al. 1988

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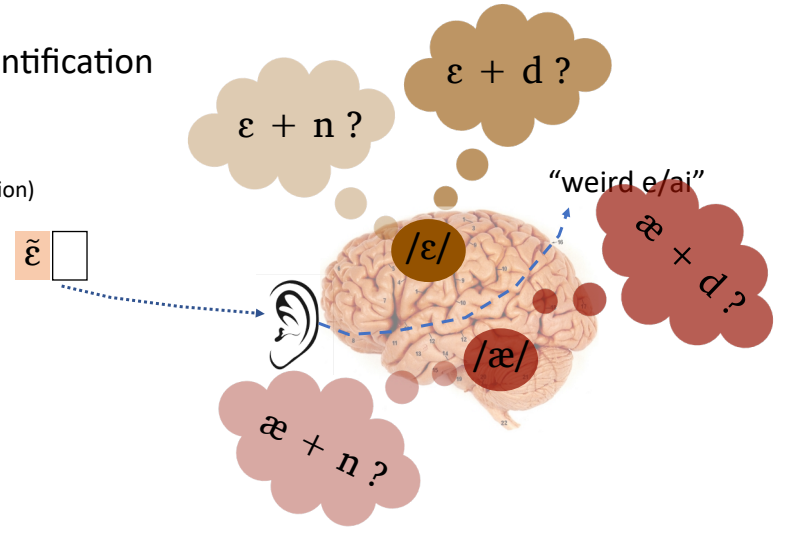
A World without Normalization?

Classification/Identification

Phoneme-level

(assuming fixed segmentation)

ɛ̃



Krakow et al. 1988

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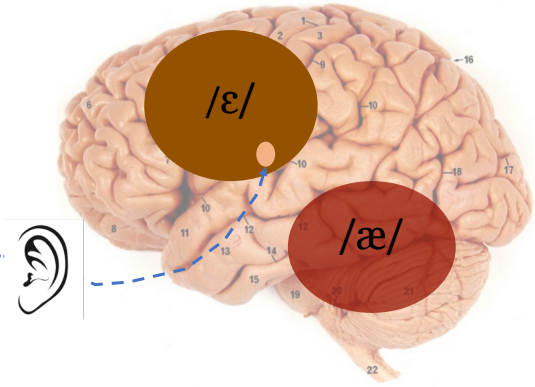
A World without Normalization?

Storage

Phoneme-level

ɛ̃ n



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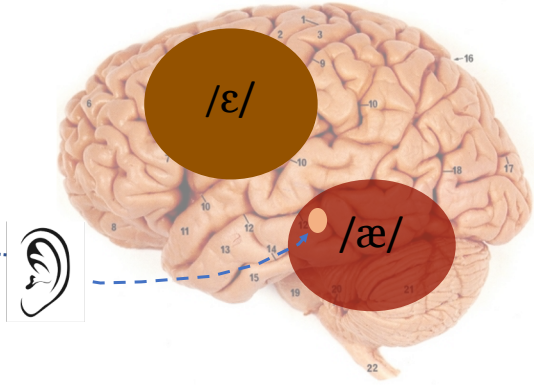
A World without Normalization?

Storage

Phoneme-level

ɛ̃



"I said I would do the dishes"

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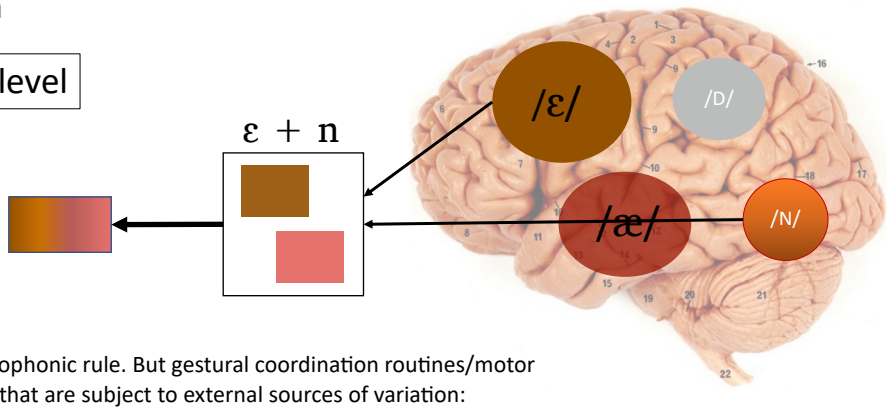
A World without Normalization?

Production

Phoneme-level



No allophonic rule. But gestural coordination routines/motor plans that are subject to external sources of variation:
Speaking rate, word predictability/frequency, ease of articulation…

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The Model (implementation is crucial)

- Synchronic variation is the result of normal speech processing
- Sound change is present in synchronic variation
  - allophony of continuously fluctuating degree
- Allophones are emergent from the interaction of
  - articulatory specification
  - gestural coordination
  - acoustic specification

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The Model

- Speaker/Listeners store:

  acoustic targets

  check/constrain output

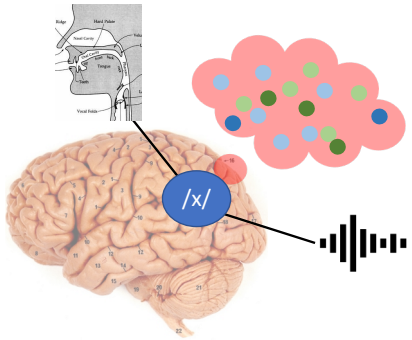
  articulatory targets

  for production to be possible

  unnormalized acoustic experiences

  short-term adaptation/accomodation

  incremental sound change



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The Model

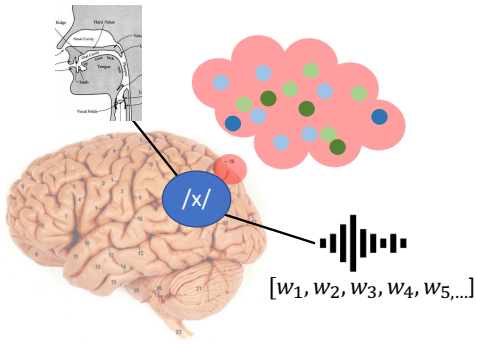
- Speaker/Listeners store acoustic targets, articulatory targets, and unnormalized acoustic experiences

  Short-term adaptation/accommodation

  Incremental sound change

- Degree of specification for each acoustic feature depends on its informativity wrt the contrast

  Phonological Specification



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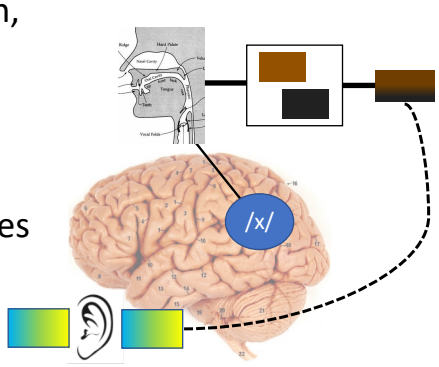
The Model

Perception

- Acoustic input is evaluated by simulation, using underlying articulatory categories
  - Local context sensitivity — Parsing window
  - Avoids normalization
- Best overall acoustic similarity determines category membership
  - Avoids normalization



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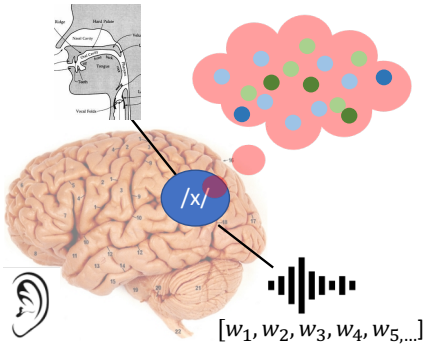
The Model

Perception

- Acoustic input is evaluated by simulation, using underlying articulatory categories
- Best overall acoustic similarity determines category membership
- Targets are directly affected by changes to the distribution of stored acoustic exemplars
  - Incremental sound change
  - Avoids actuation paradox



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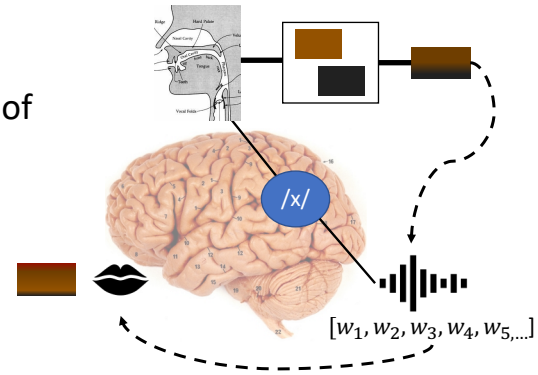
The Model

Production

- Articulatory targets are perturbed by: production error and gestural overlap of adjacent units
- Ultimate acoustic realization is constrained by degree of specification of each individual feature

Emergent Allophony



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Thank You!

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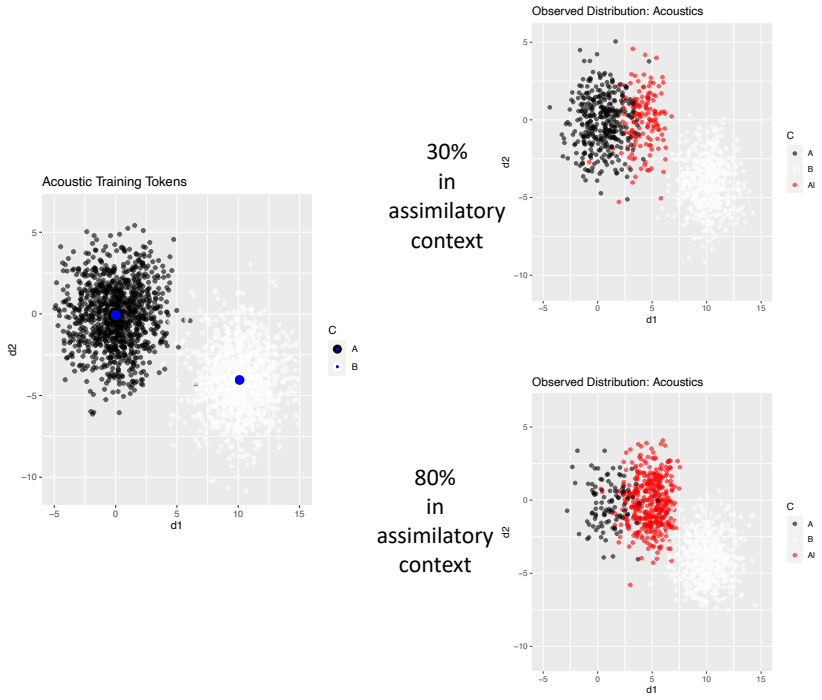

- No acoustic normalization
- Acoustic targets updated from acoustic clouds
- Weights updated from acoustic clouds
- Fixed articulatory targets
- Range of allophony constrained by weight values

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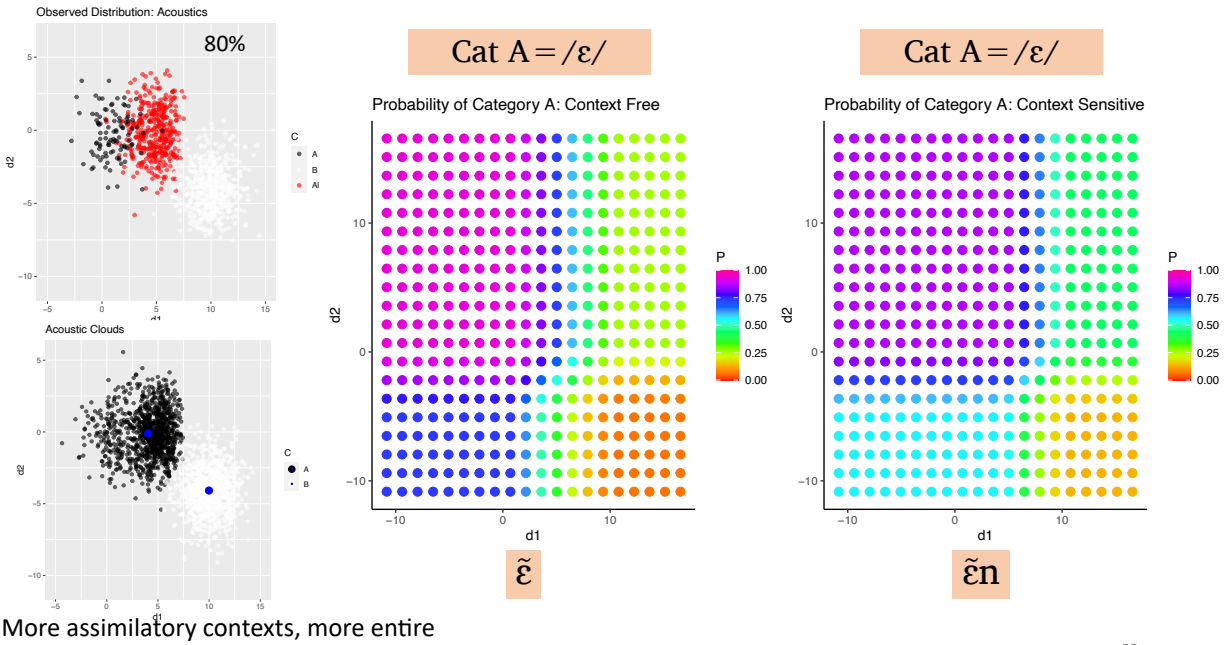

More assimilatory contexts, more entire category is shifted: bug or feature?

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