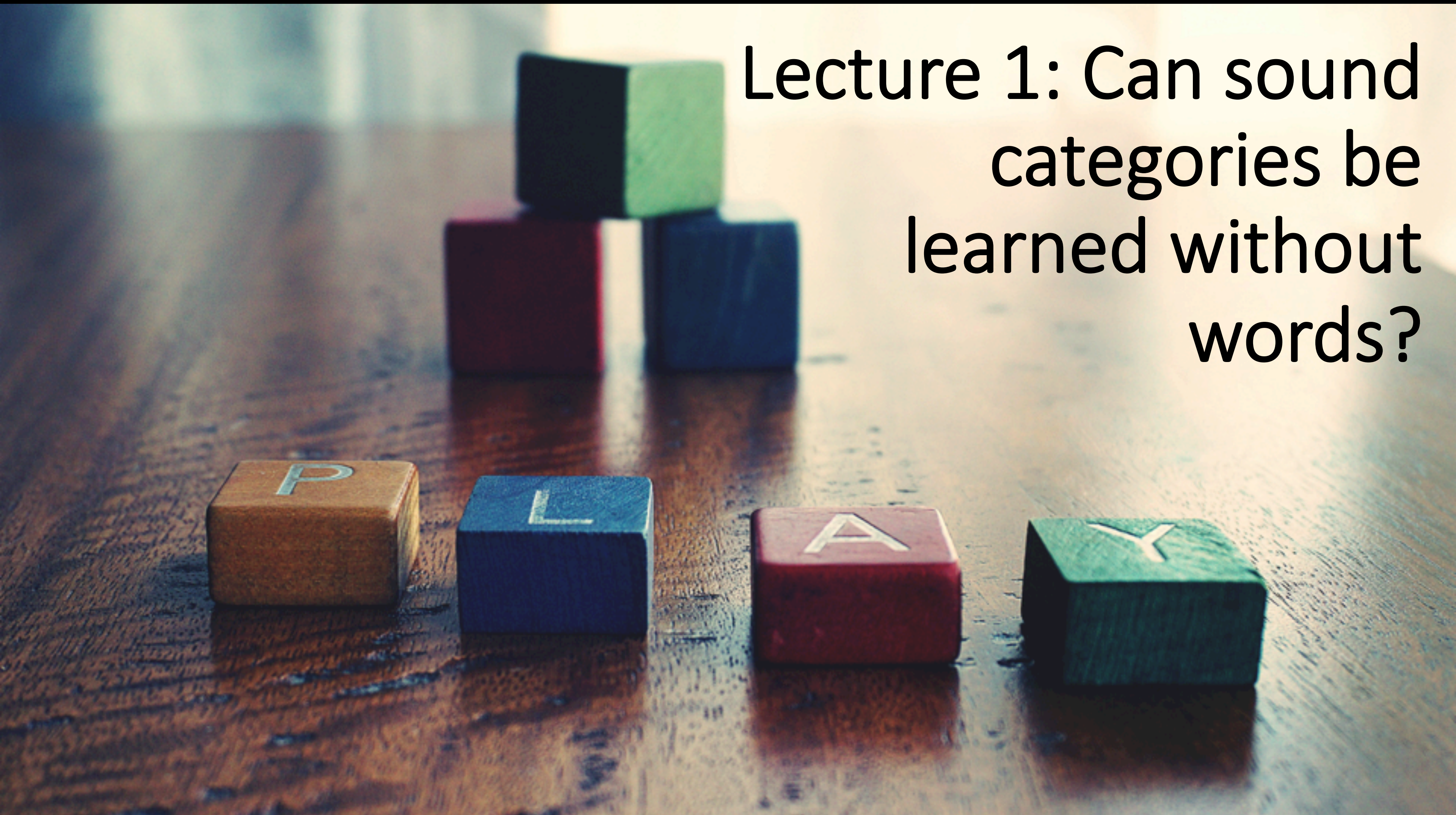
The relationship between early phonological and lexical development

Lecture 1: Can sound categories be learned without words?



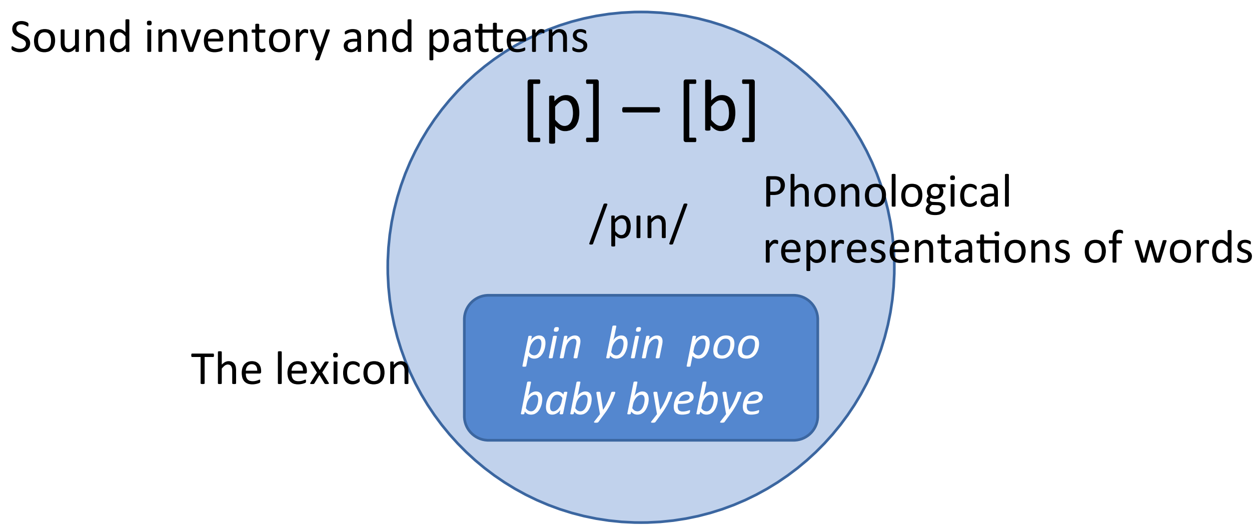
Mits Ota
University of Edinburgh

Summer School of Linguistics, 2019
mits-ota.github.io/SSoL2019.html

What these lectures are about

The big question: *How are early phonological development and lexical development related to each other?*

What infants learn:

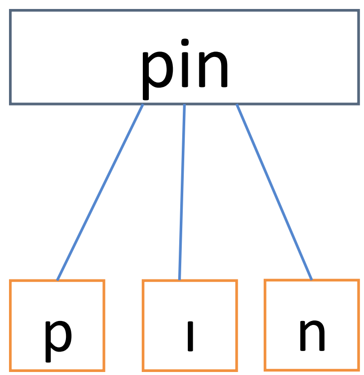


Why (I think) this is an important question

Duality of patterning – a key design feature of human language (Hocket, 1958).

Morphemes/words

Limitless supply of meaningful units



Phonemes

Finite set of meaningless units

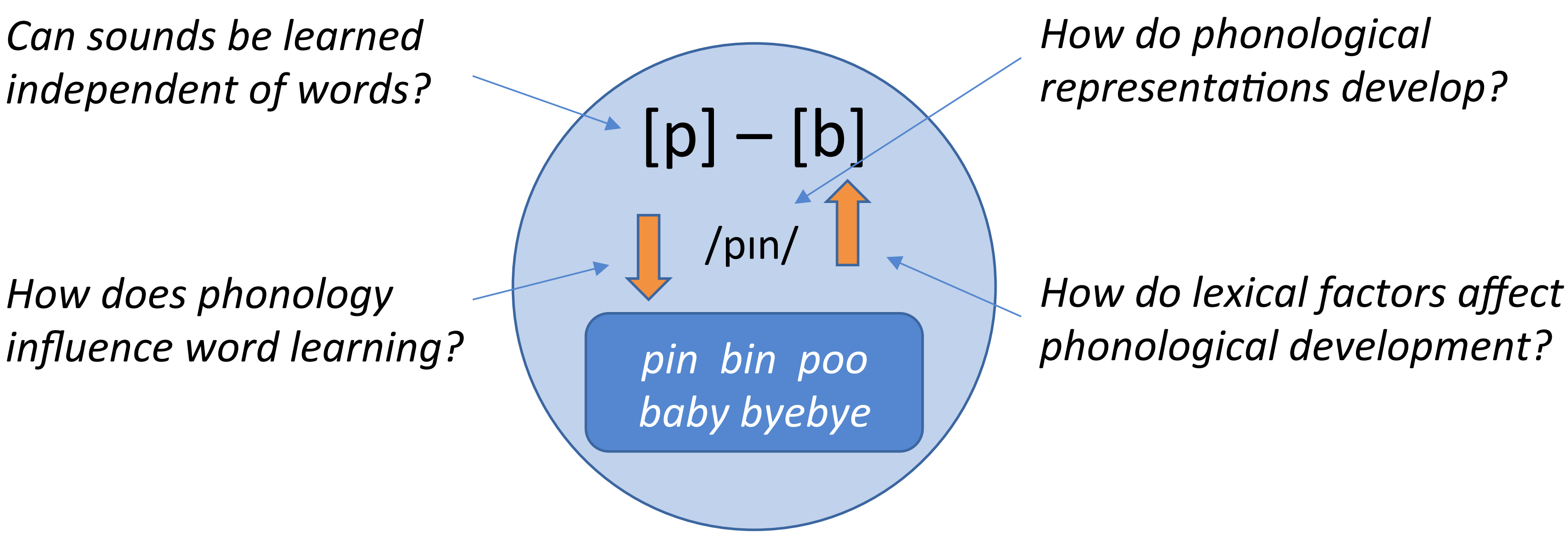
How does the learner break into this interdependence?

Why (I think) this is an important question

Although learning phonology and learning words are intertwined, we tend to study – and *teach* – them separately.

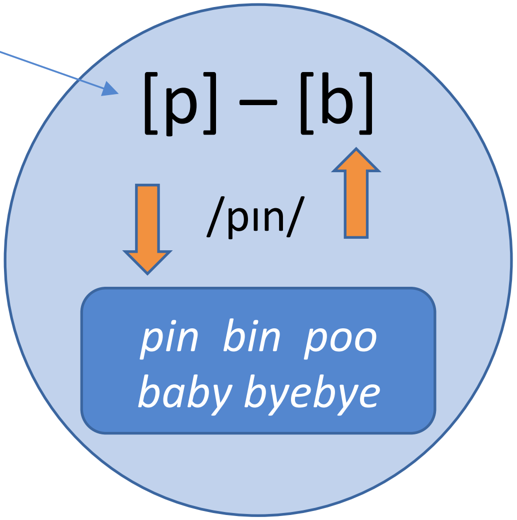
Table of contents from *Child Language Acquisition* (Ambridge & Lieven, 2011)

The components



This lecture

Can sounds be learned independent of words?



Part 1

When do infants begin to learn sound categories and words?

Newborns and very young infants can discriminate acoustic differences along most phonetic dimensions

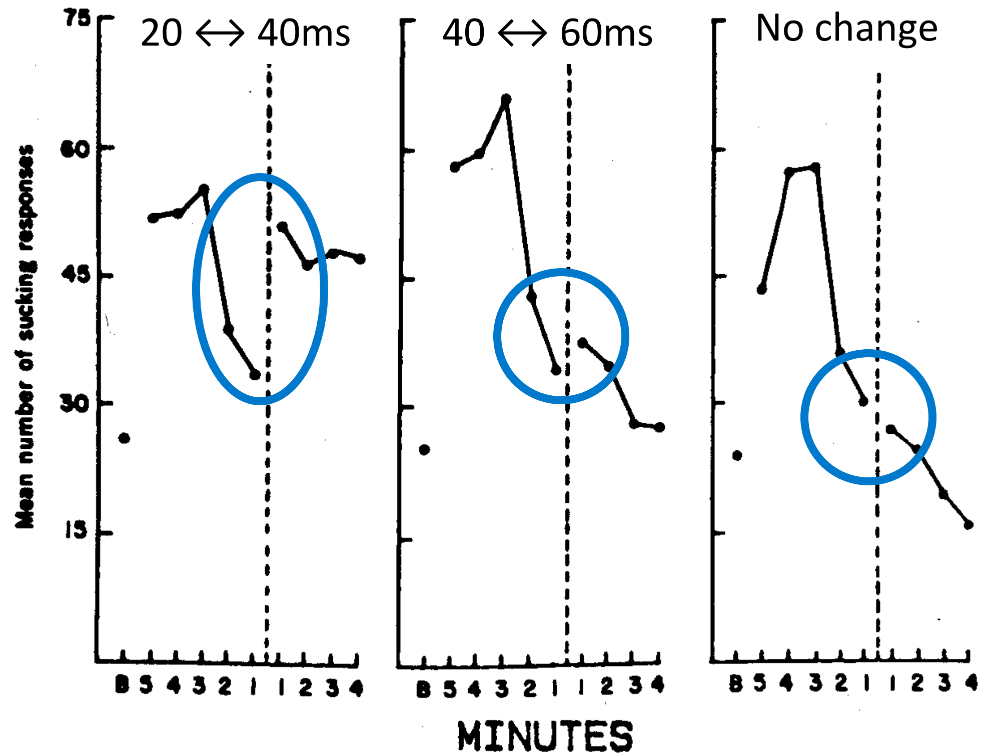
- Voicing (e.g., /d/-/t/)
- Place of articulation (e.g., /b/-/d/-/g/; Bertoncini et al., 1987)
- Manner (e.g., /b/-/w/; Eimas & Miller, 1980)
- Vowels (e.g., /a/-/i/; Trehub, 1973)
- Stress (e.g., báda-badá; Jusczyk & Thompson, 1978)
- Pitch contour (e.g., ame-ame; Nazzi at al., 1998)

They can even discriminate sounds that are not contrastive in their ambient language

- Kikuyu 1- to 4-month-olds: [ba]-[pa] (Streeter, 1976)
- Anglo Canadian 1- to 4-month-olds: [pa]-[pã], [řa]-[ʒa] (Trehub, 1976)
- Anglo Canadian 6-month-olds: [ţa]-[ṭa], [‘ki]-[‘qi] (Werker & Tees, 1984)
- English 4-½-month-olds: [u]-[y] (Polka & Werker, 1994)

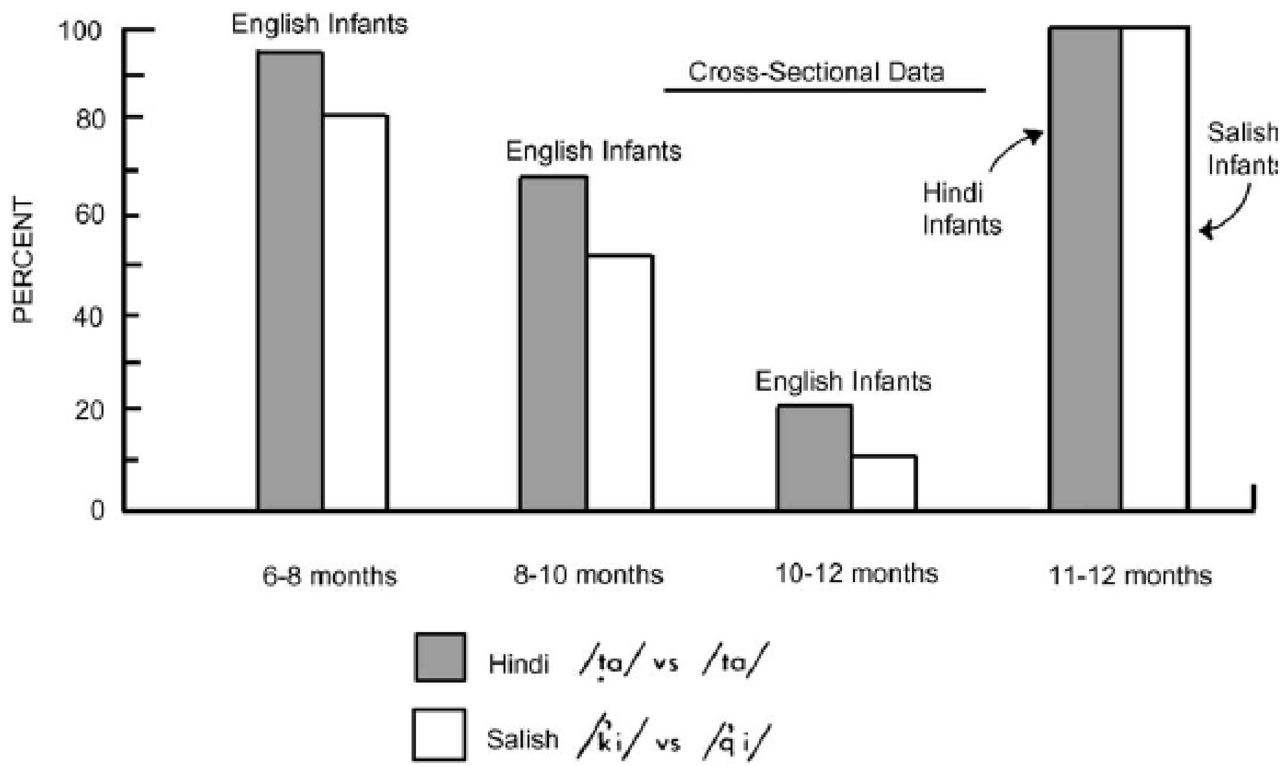
Infants’ early speech discrimination is categorical

High-Amplitude Sucking procedure



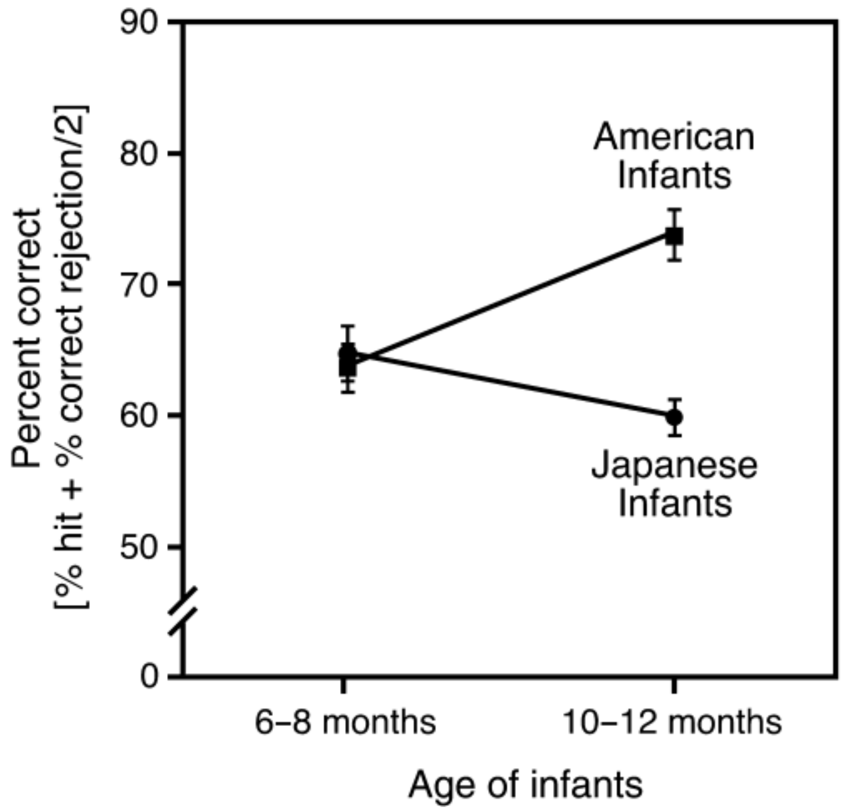
1- to 4-month-olds’ reaction to changes in voice-onset time (Eimas et al., 1971)

Sensitivity to *non-native* contrasts declines around 8-10 months



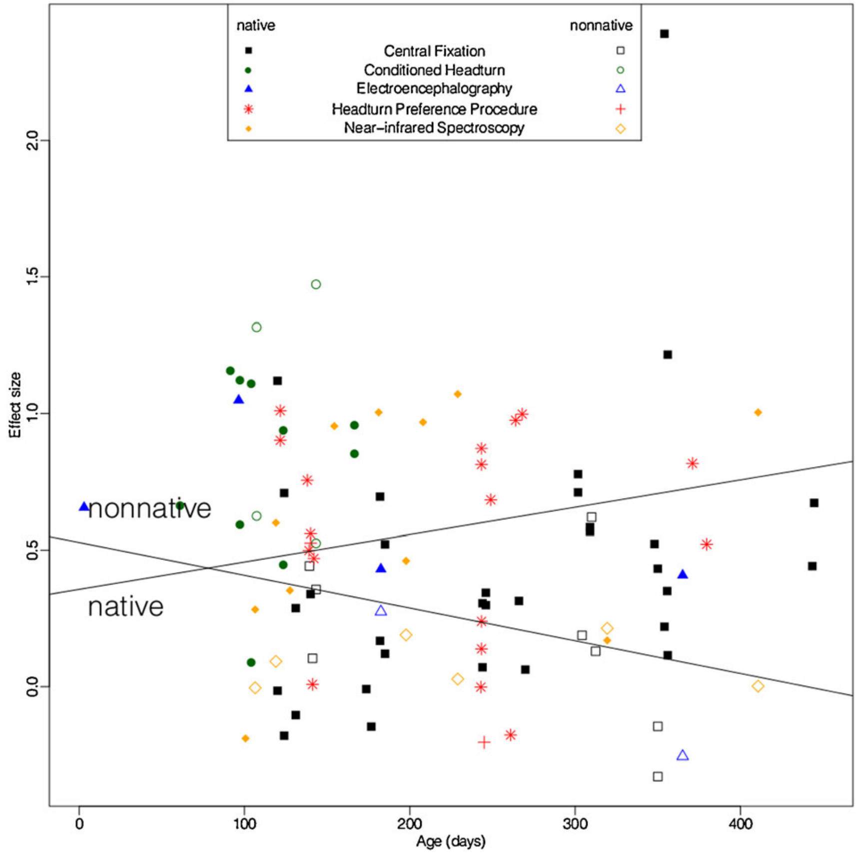
Discrimination of retroflex vs. dental stops and glottalized velar vs. uvular stops (Werker & Tees, 1984)

Sensitivity to *native* contrasts sharpens around 8-10 months



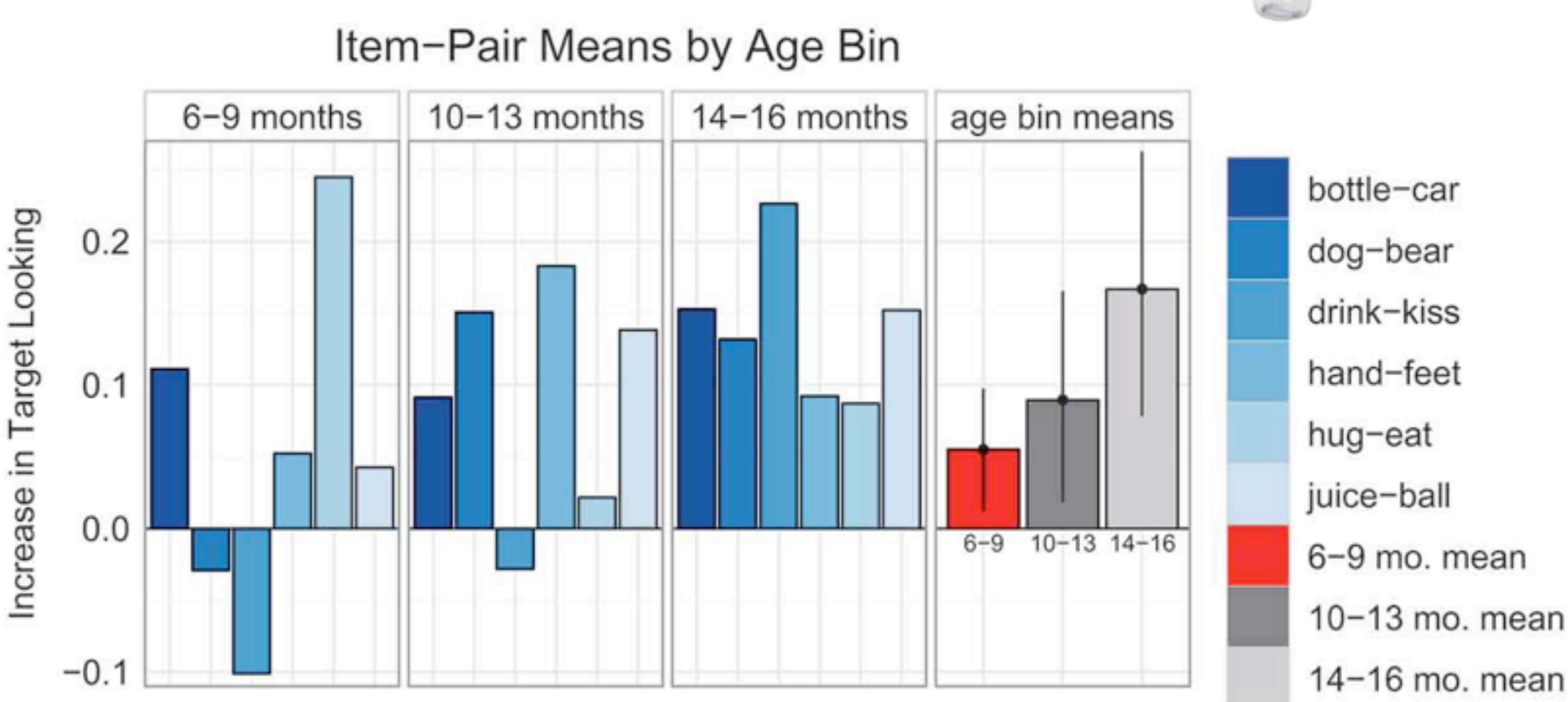
Discrimination of AE /ra-la/contrast by American and Japanese infants (Kuhl et al., 2006)

This pattern of perceptual attunement applies to vowels too



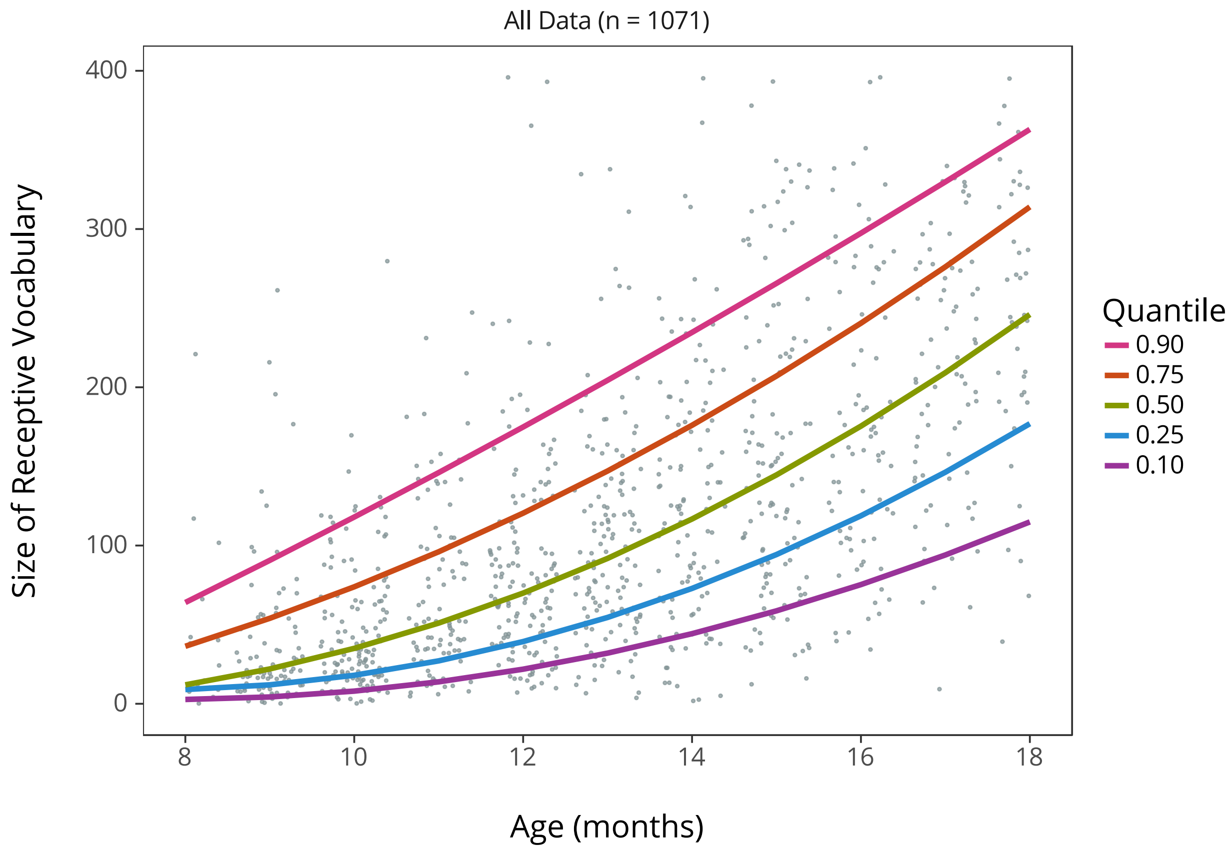
Meta-analysis of vowel contrast discrimination (Tsuji & Cristia, 2014). Nativeness effects emerge between 6-10 months.

Infants begin to understand some words around 6-9 months



Preferential looking with two objects and one word (Bergelson & Swingley, 2012)

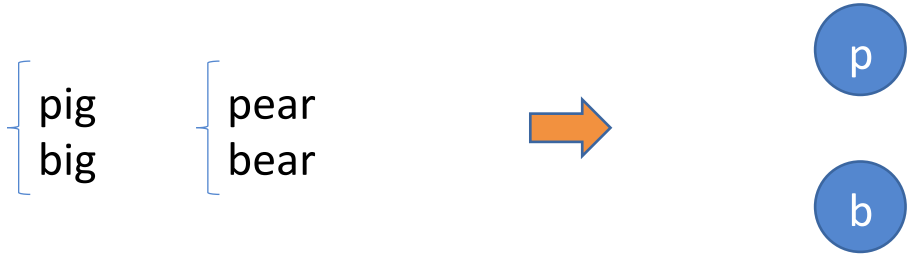
Infants begin to understand some words around 6-9 months



Parental report (CDI) data from Wordbank (American English) (Frank et al., 2017)

The minimal-pair hypothesis

- Infants begin to comprehend some basic words around 6-9 months, when perceptual attunement to native contrasts occurs.
- So, maybe infants are using **minimal pairs** to learn contrasts (MacKain, 1982).



Problem: The initial lexicon is too small to offer enough minimal pairs

Rank	Word	% sample	Rank	Word	% sample
1.	mommy	95.0	26.	[a]DRINK	58.1
2.	daddy	93.5	27.	keys	56.3
3.	[a]bye	88.6	28.	[a]DON'T	55.8
4.	[a]no	86.3	29.	comb	55.4
5.	[a]peekaboo	84.3	30.	nose	55.4
6.	bath	76.2	31.	[a]HUG	54.9
7.	ball	75.0	32.	banana	54.4
8.	bottle	75.0	33.	cookie	54.2
9.	[a]hi	74.0	34.	bathtub	53.2
10.	[a]allgone	71.9	35.	balloon	52.9
11.	dog	70.8	36.	milk	52.9
12.	book	68.7	37.	cat	52.7
13.	[a]night-night	68.5	38.	cracker	52.7
14.	diaper	67.4	39.	telephone	52.6
15.	[a]*KISS*	66.2	40.	[a]yes	52.6
16.	[a]uh-oh	65.1	41.	cheerios	51.4
17.	[a]pattycake	62.6	42.	bird	50.4
18.	juice	61.9	43.	[a]yum-yum	50.4
19.	shoe	61.9	44.	grandpa	50.1
20.	baby	61.6	45.	woof	49.5
21.	grandma	61.3	46.	[a]DANCE	49.3
22.	outside	61.0	47.	baa-baa	49.0
23.	car	60.1	48.	meow	48.3
24.	[a]EAT	59.7	49.	[a]LOOK	48.2
25.	kitty	58.8	50.	mouth	48.2

First 50 English words in comprehension (Caselli et al., 1995)

Problem: The initial lexicon is too small to offer enough minimal pairs

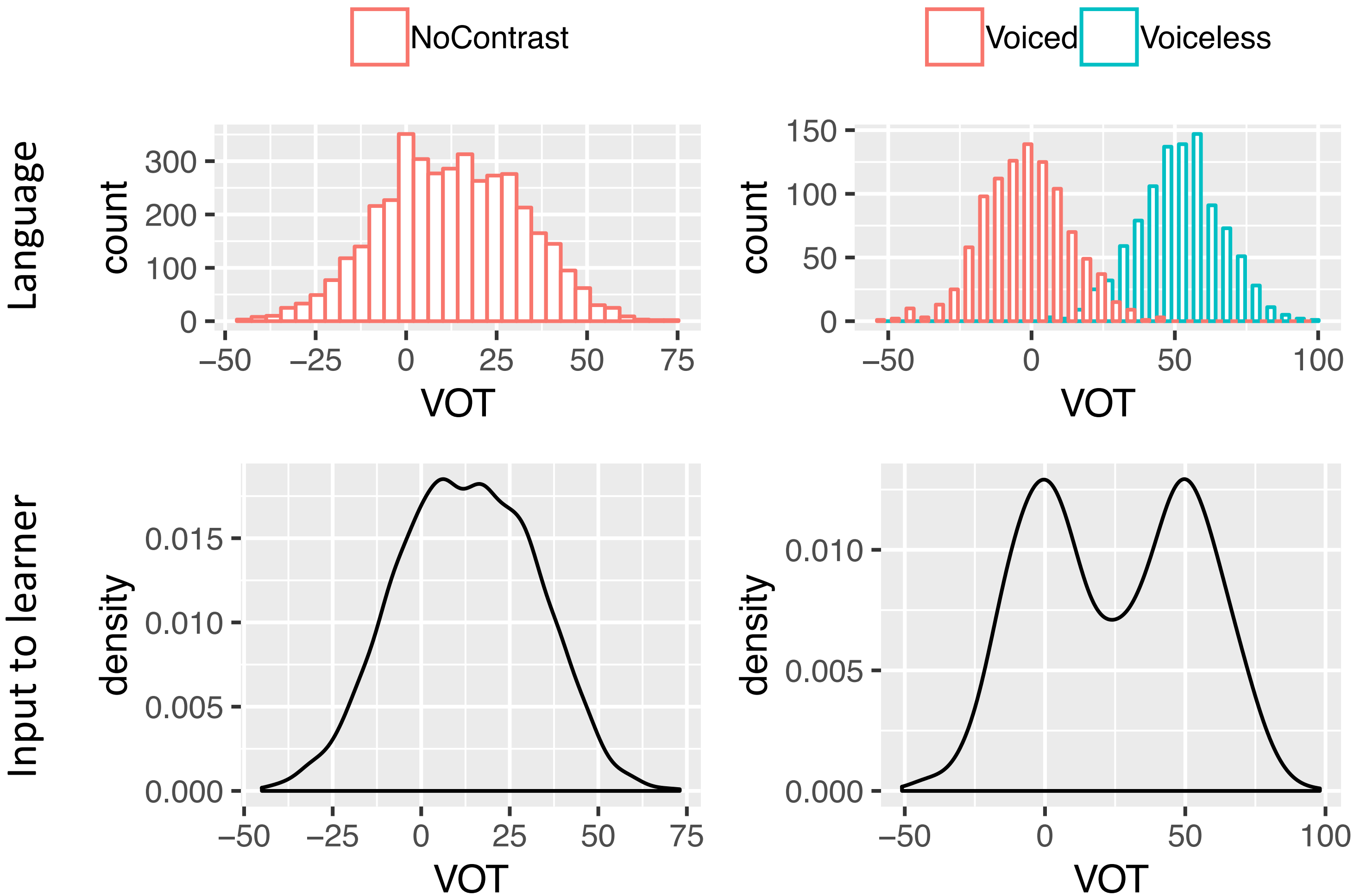
Word	Translation	% samp
mamma	mommy	91.3
papa	daddy	88.2
(child's own name)	—	82.6
[a]ciao	hi/bye	82.6
[a]pappa	(food/mealtime)	81.1
[a]cuccu-settete	(hiding game)	81.0
acqua	water	79.0
[a]no	no	77.9
palla	ball	75.9
bau-bau	(dog sound)	75.4
nonna	grandma	75.4
cane	dog	74.9
biberon	bottle	71.8
telefono	telephone	70.3
[a]bravo	good	67.7
nonno	grandpa	66.7
scarpe	shoes	66.2
biscotto	cookie	65.6
[a]*BERE*	to drink	65.1
miao	(cat sound)	64.6
latte	milk	64.1
[a]nanna	(sleep/bedtime)	63.6
mano	hand	63.1
[a]basta	(enough/stop)	62.6
[a]pane	bread	62.6
[a](fare) bagno	(have/do) bath	62.1
[a]gatto	cat	62.1
bimbo	child	60.5
[a]*DARE*	to give	59.5
[a]*MANGIARE*	to eat	59.5
piede	foot	59.0
[a]*BACIARE*	to kiss	59.0
[a]*BALLARE*	to dance	59.0
automobile	car	57.9
[a]non c'è più	(is no more)	56.9
panolino	diaper	56.9
[a]si	yes	56.9
bavaglino	bib	56.4
capelli	hair	56.4
bocca	mouth	55.9
bicchiere	glass	54.9
uccellino	bird	54.4
passegino	stroller	53.8
[a]pronto	(hello on phone)	53.3
ciuccio	pacifier	51.3
letto	bed	51.3
naso	nose	50.3
televisione	television	
[a]*ANDARE*	to go	49.2
cucchiaio	spoon	49.2
[a]*PETTINARE*	to comb	49.2
[a]*SALUTARE*	to greet	49.2

First 50 Italian words in comprehension (Caselli et al., 1995)

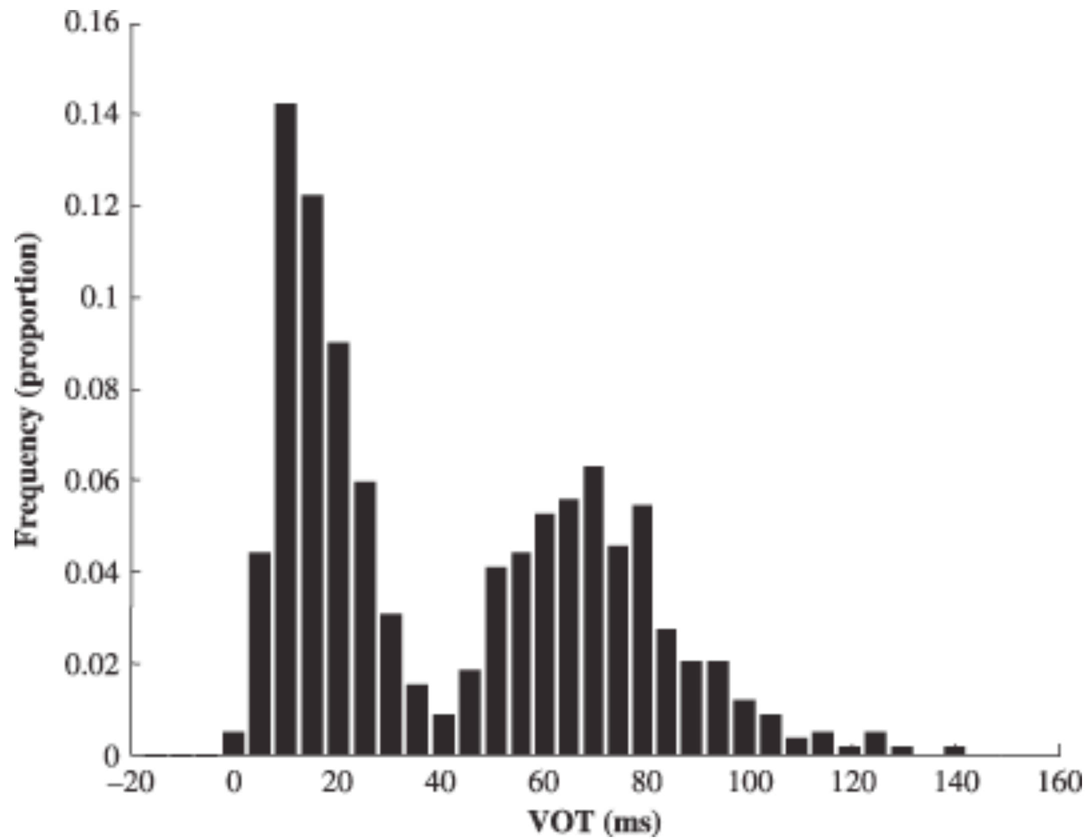
Part 2

Distributional learning from phonetic input

Distributional learning: Bimodal phonetic distribution signals contrasts (Guenther & Gjaja, 1996)

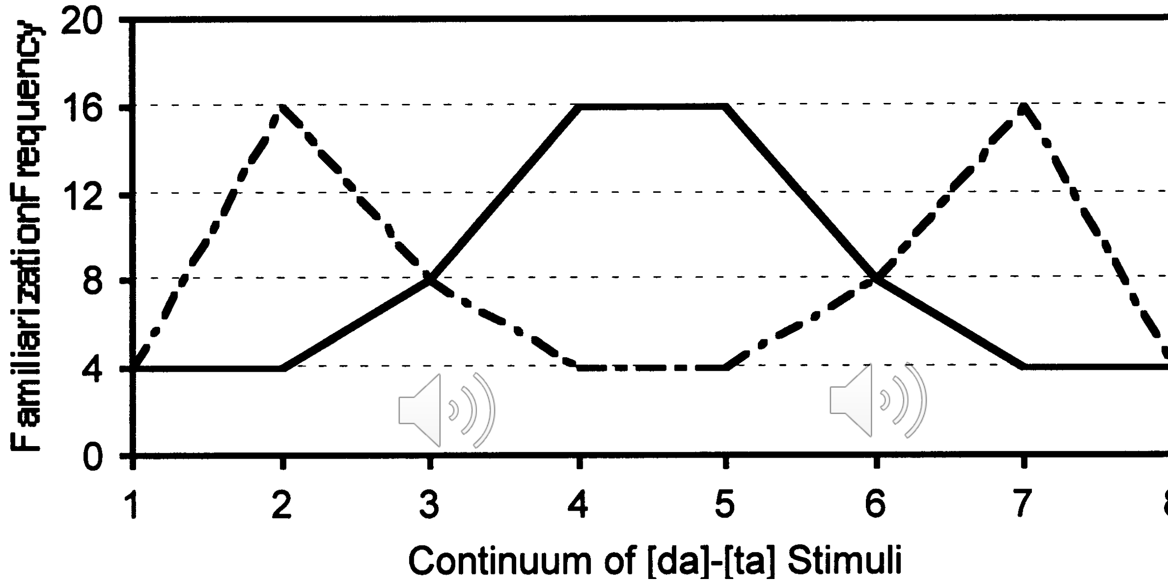


This seem to capture the reality of the input (at least for certain contrasts)



Bimodal distribution of VOT in adult English (Allen & Miller, 1999)

Infants can perform phonetic distributional learning in the lab



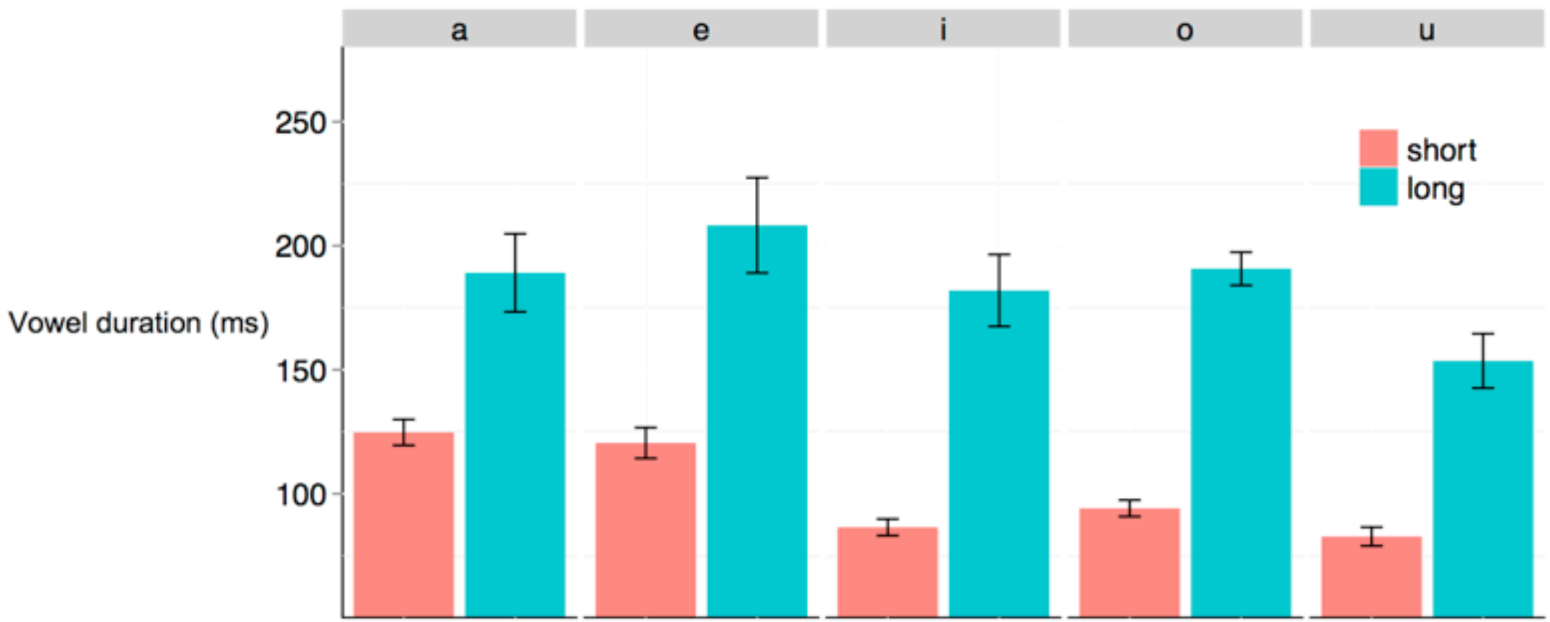
	Alternating trials (s)	Non-Alternating trials (s)
6 months Unimodal	4.85 (0.47)	4.53 (0.51)
8 months Unimodal	4.98 (0.63)	5.20 (0.56)
6 months Bimodal	5.66 (0.44)	6.41 (0.32)
8 months Bimodal	5.45 (0.52)	6.15 (0.56)

Maye, Werker, & Gerken (2002)

Distributional learning from phonetic input (DLfPI) is adaptable

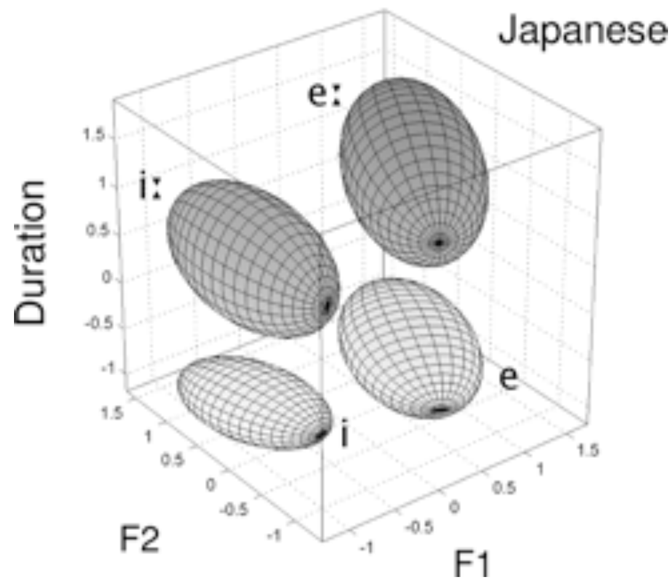
- DLfPI generalizes to featurally-related contrasts: e.g., training along /k-g/ -> learned effects on /t-d/ (6- and 8-month-olds; Maye, Weiss, & Aslin, 2008)
- DLfPI works on multi-dimensional contrasts: e.g., Polish retroflex [ça] vs. alveopalatal [şa] sibilants ~ peak in fricative spectra x F2 (4-6 month-olds; Cristia et al., 2011)

Problems with DLfPI (1): Skewed frequency distribution (e.g., Japanese vowel length)



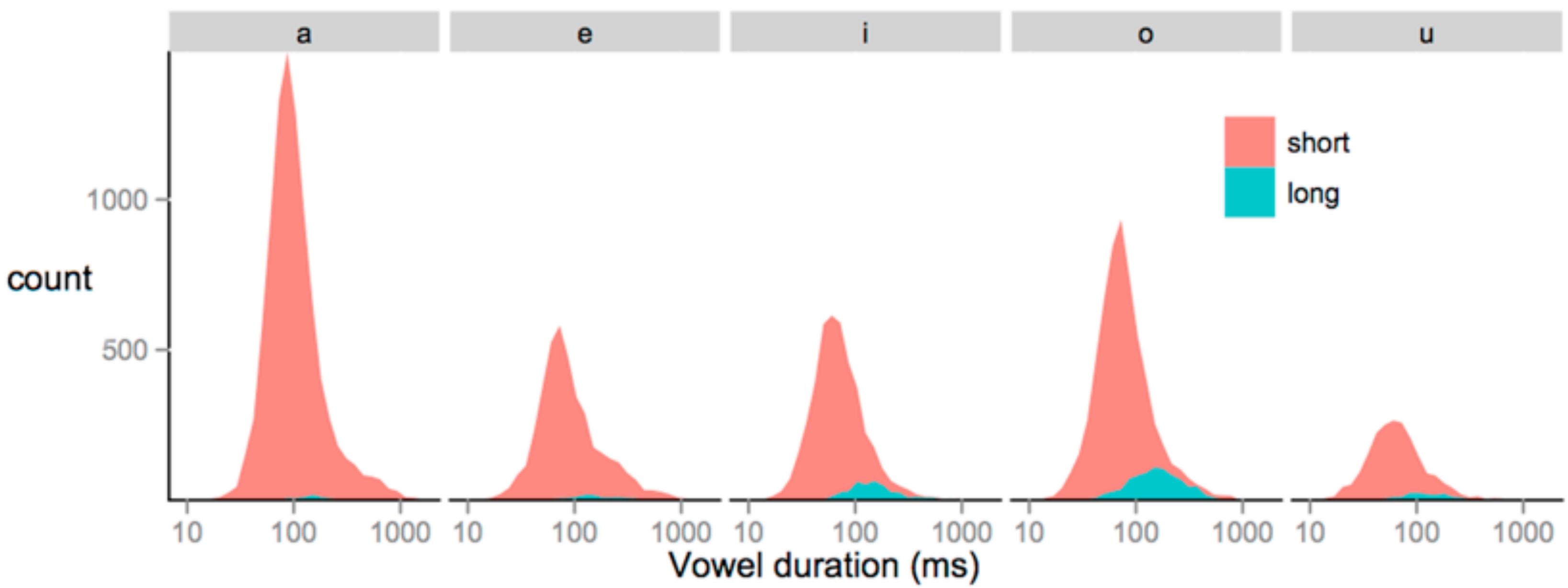
Mean duration of short vs. long vowels in Japanese (Bion et al. 2013)

Problems with DLfPI (1): The distribution looks learnable from lab-based data



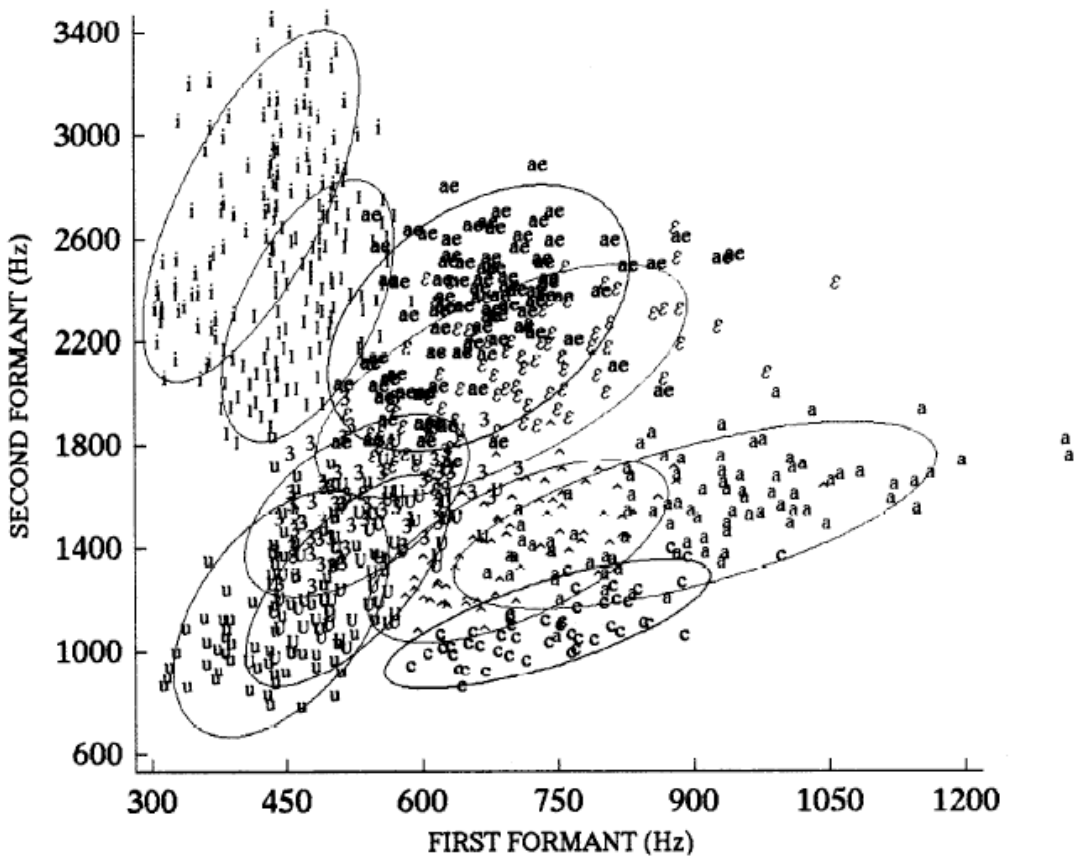
Distributions of Japanese /i, i:, e, e:/ in lab-elicited infant-directed speech (Vallabha et al. 2007)

Problems with DLfPI (1): But not from real IDS due to skewed frequency distributions



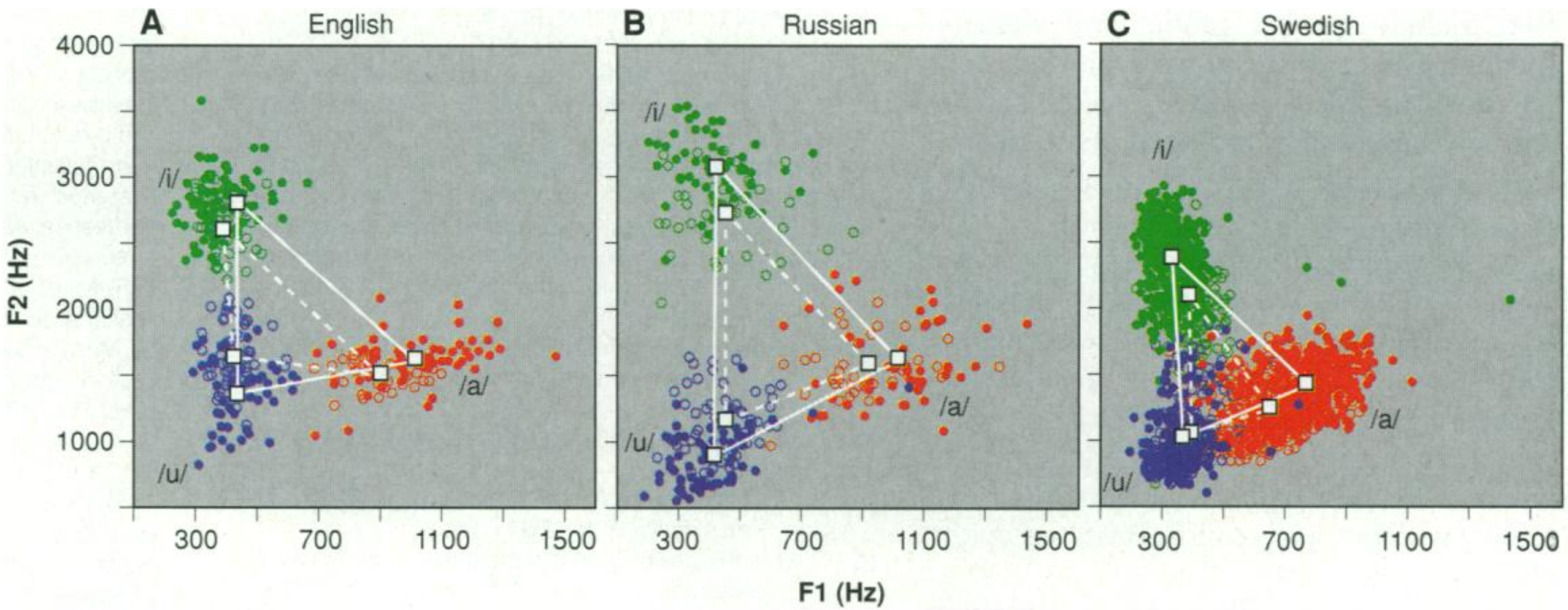
Frequency distribution of vowel duration in corpus data of naturalistic infant-directed speech (Bion et al. 2013)

Problems with DLfPI (2): Extensive overlap



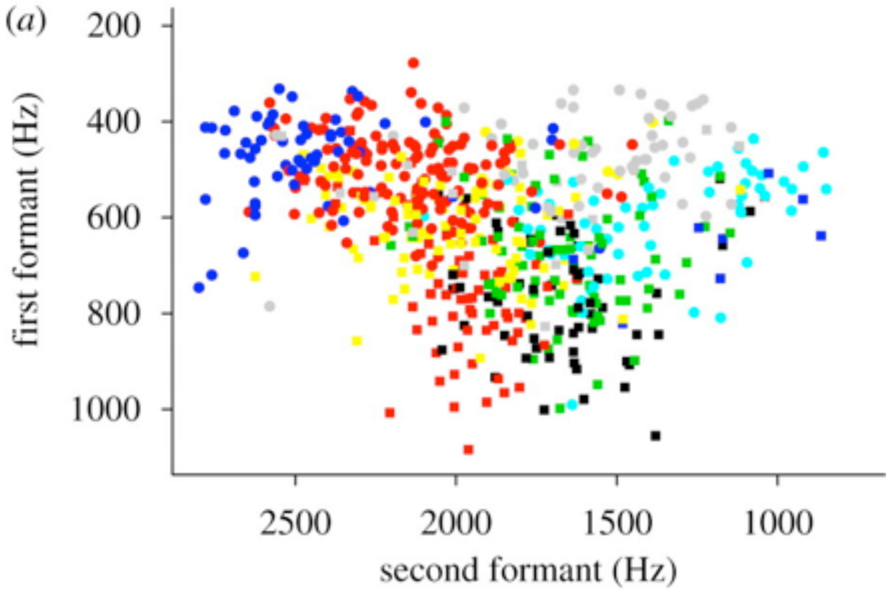
Twelve English vowels produced by men, women and children (Hillenbrand et al. 1995)

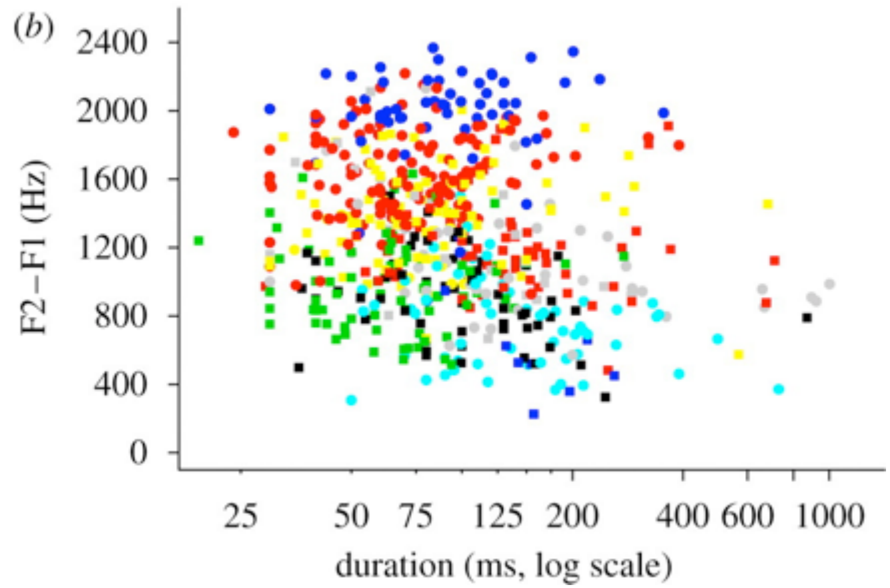
Problems with DLfPI (2): Can hyper-articulation in IDS help?



Vowel triangles formed by the point vowels, /i/ (green), /a/ (red) and /u/ (blue) in infant-directed (solid line) vs adult-directed speech (Kuhl et al., 1997)

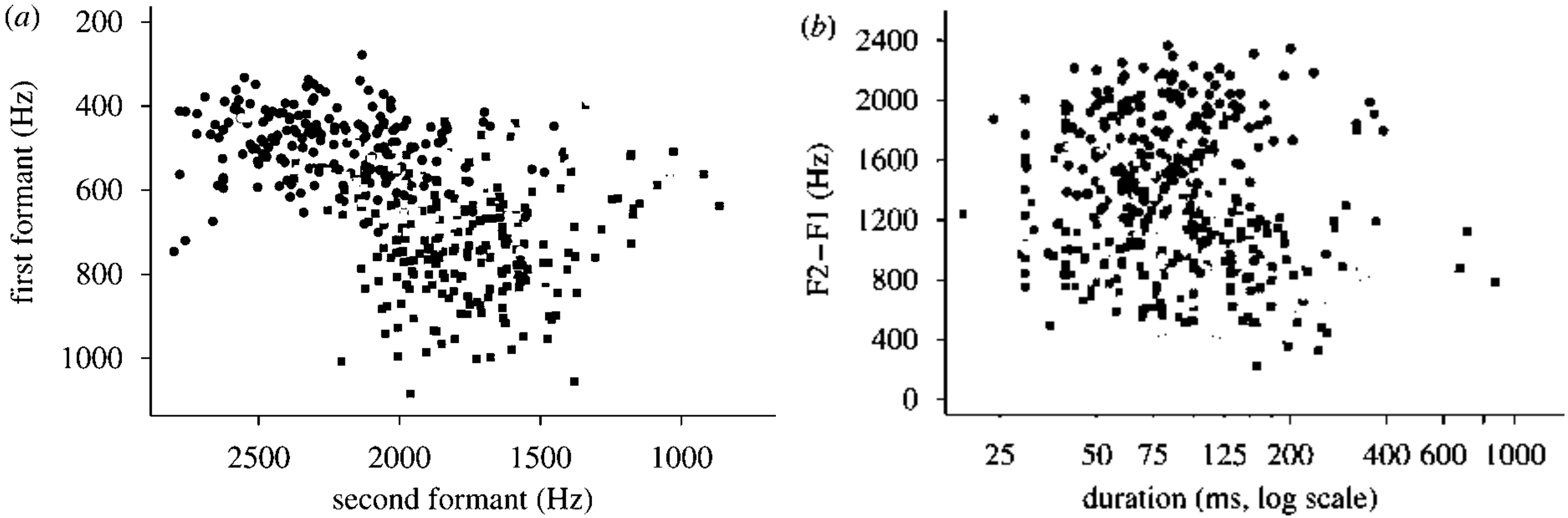
Problems with DLfPI (2): Not really! Still overlapping when you look at all vowels





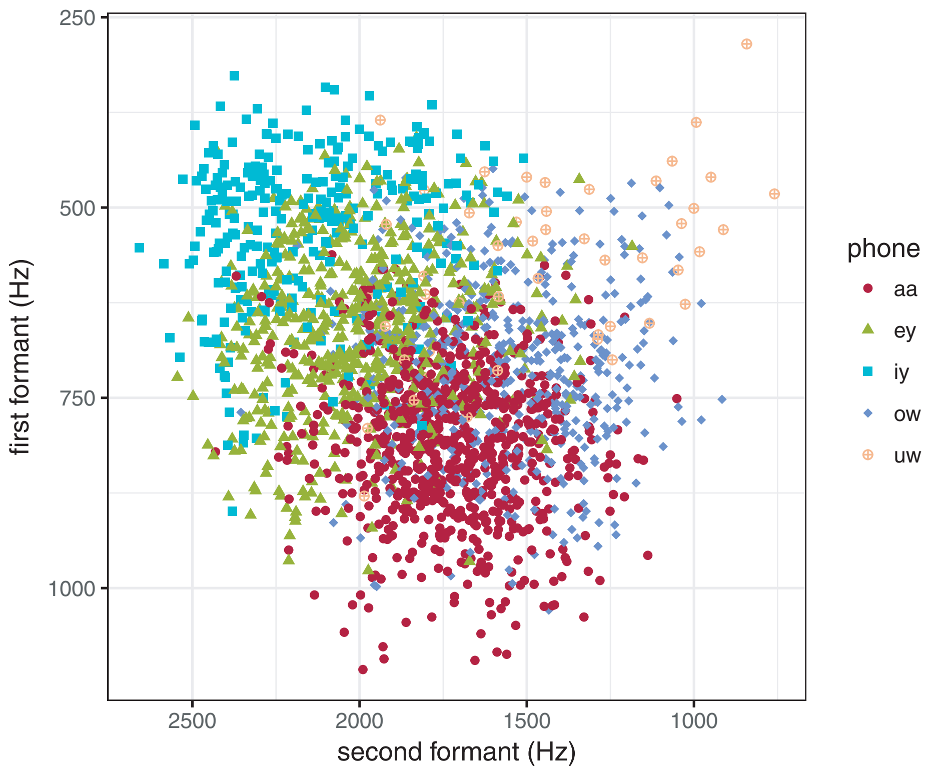
F1/F2 and F2-F1/duration of 700 vowels produced naturally by one mother (Swingley, 2009)

Problems with DLfPI (2): Not really! Still overlapping when you look at all vowels



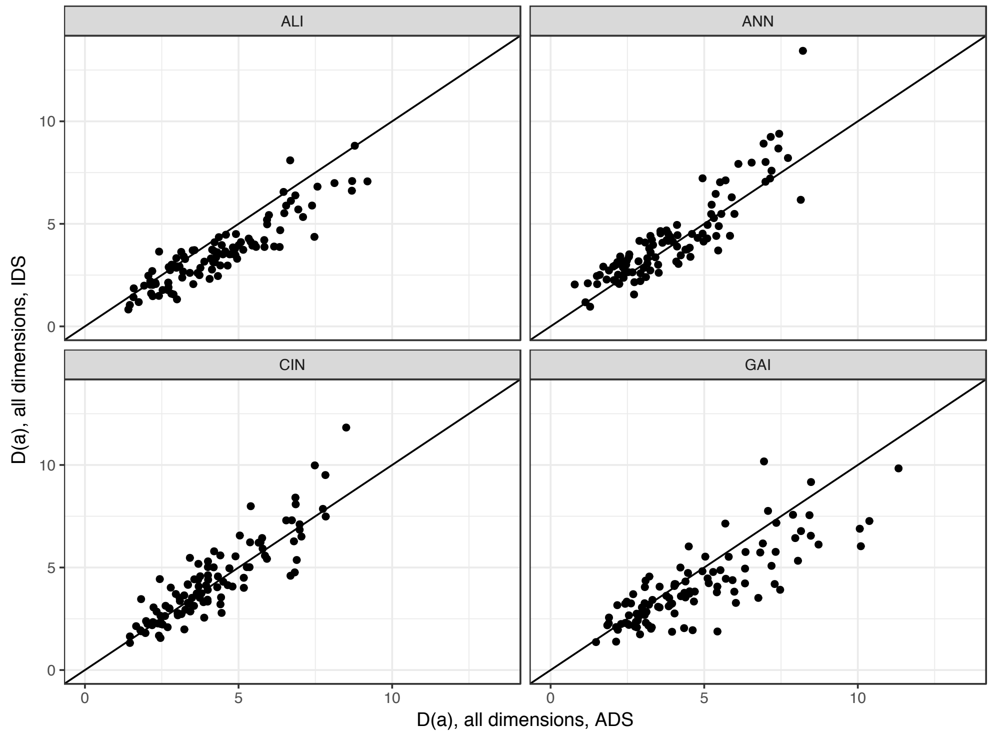
F1/F2 and F2-F1/duration of 700 vowels produced naturally by one mother (Swingley, 2009)

Problems with DLfPI (2): And challenging even in a simpler vowel system



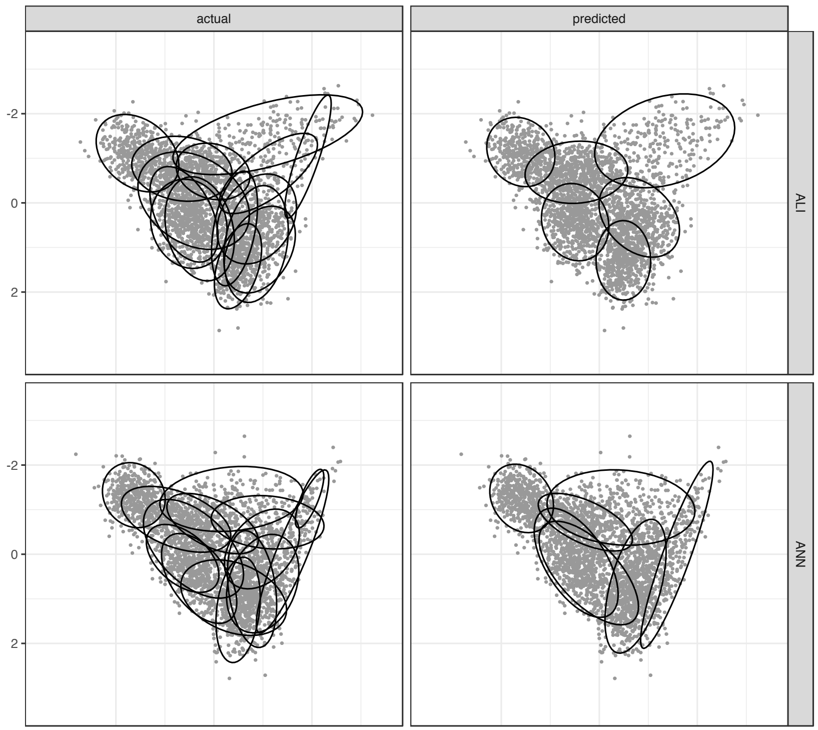
F1/F2 of 2,200 vowels in Spanish infant-directed speech (Swingley & Alarcon, 2018)

Problems with DLfPI (2): Adding more phonetic dimensions doesn't help



Degrees of phonetic overlap between IDS vs ADS English vowels in multi-dimensional space (F1, F2, F3, F1/F2 change + duration) (Starling, 2018)

Problems with DLfPI (2): Adding more phonetic dimensions doesn't help

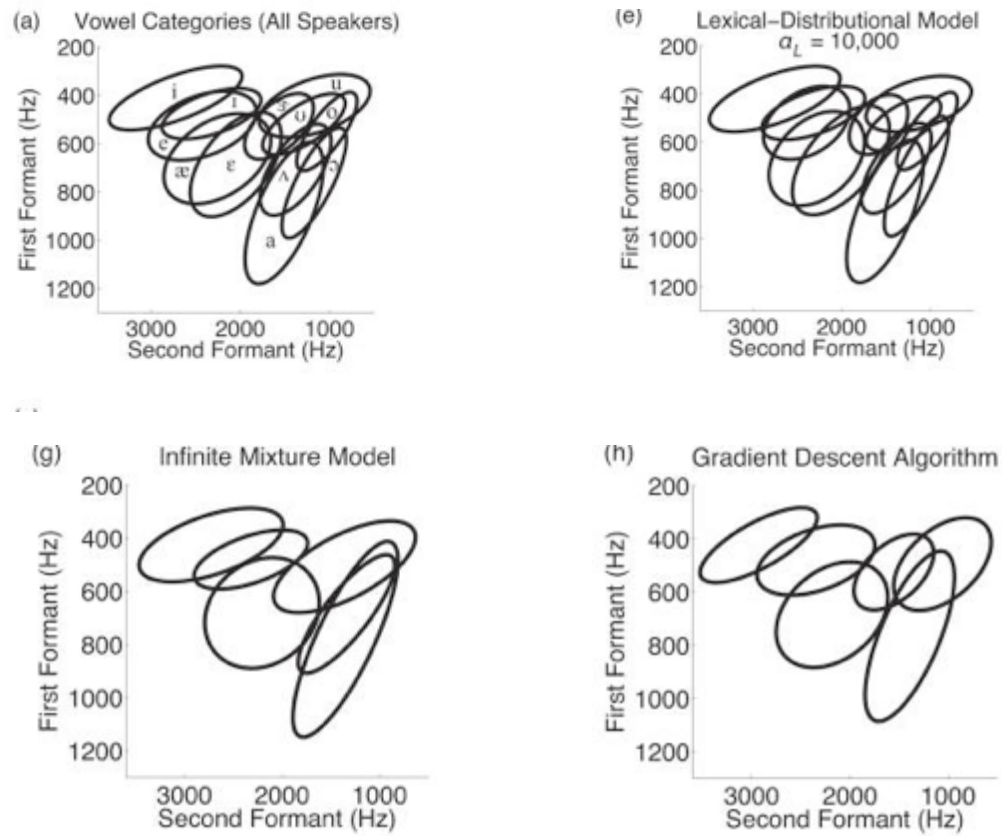


Actual categories in IDS (left) compared to outputs of BIC-based clustering models (Starling, 2018)

Part 3

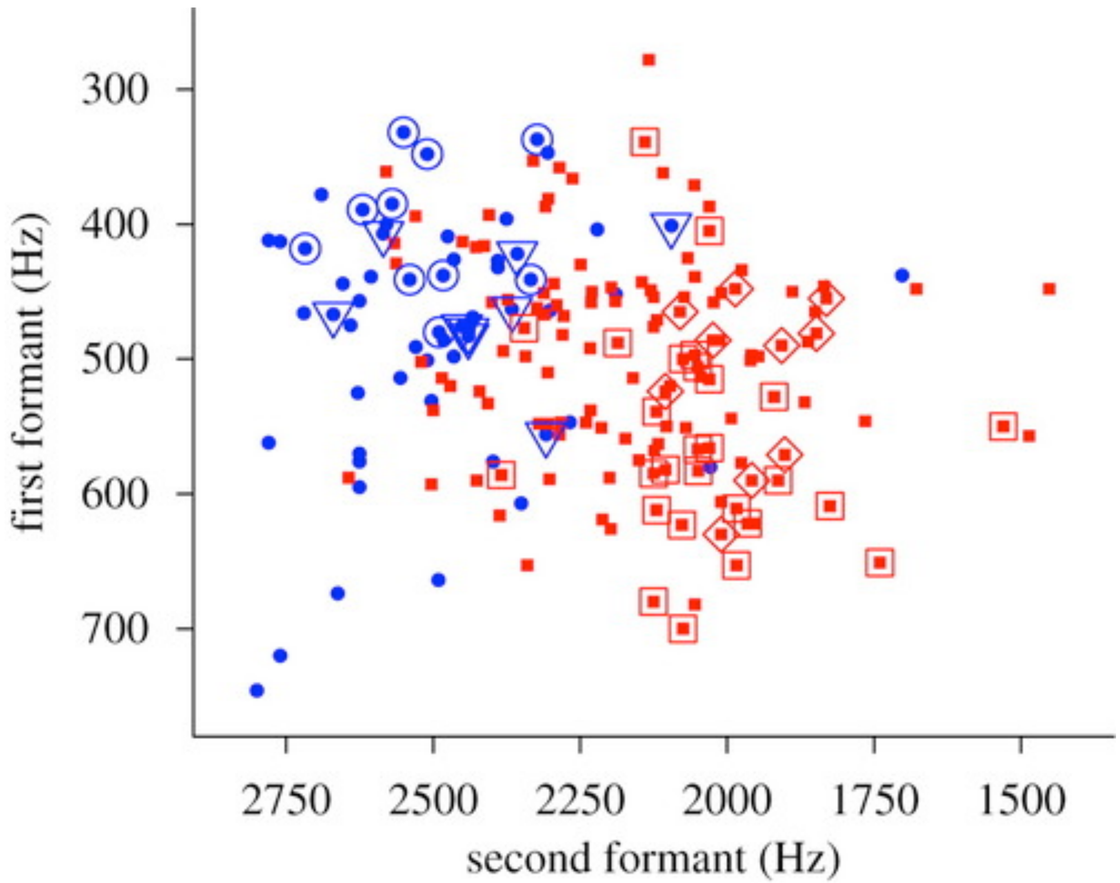
Back to words: The role of lexical information in sound category learning

Vowel learning by computer models improves when lexical info is added



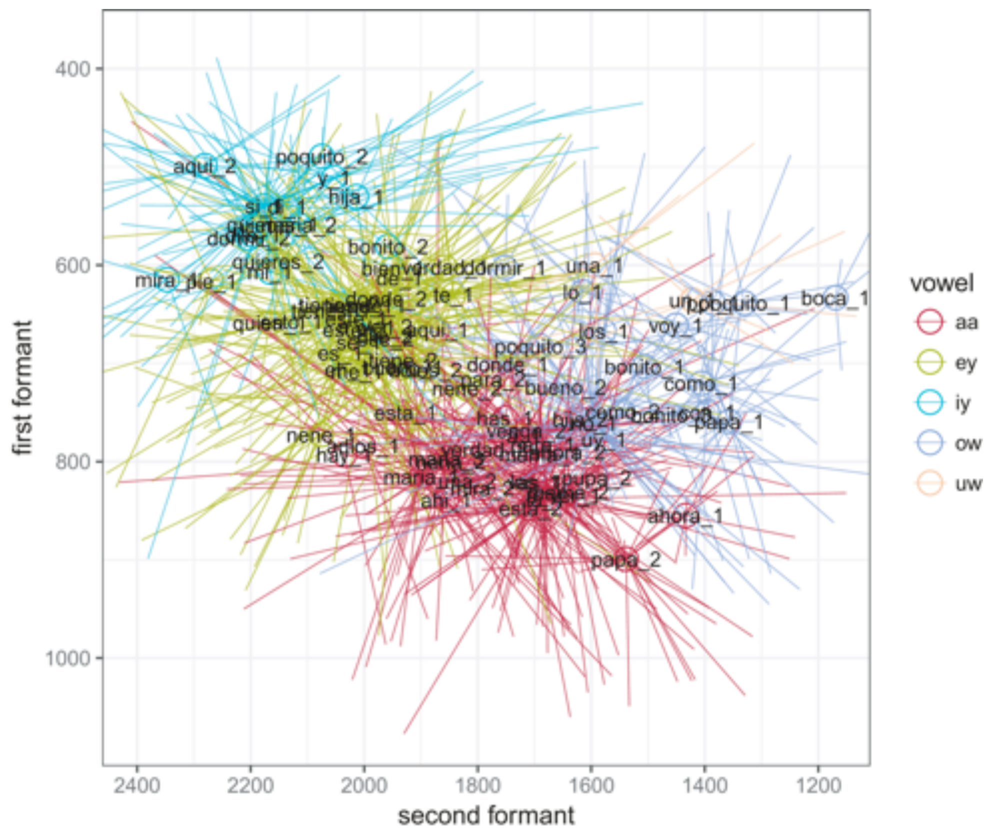
The Hillenbrand data vs. simulations with the lexical-distributional model, infinite mixture model and gradient descent algorithm (Feldman, Griffiths, et al., 2013)

Why? Because words serve as anchors of phonetic variation



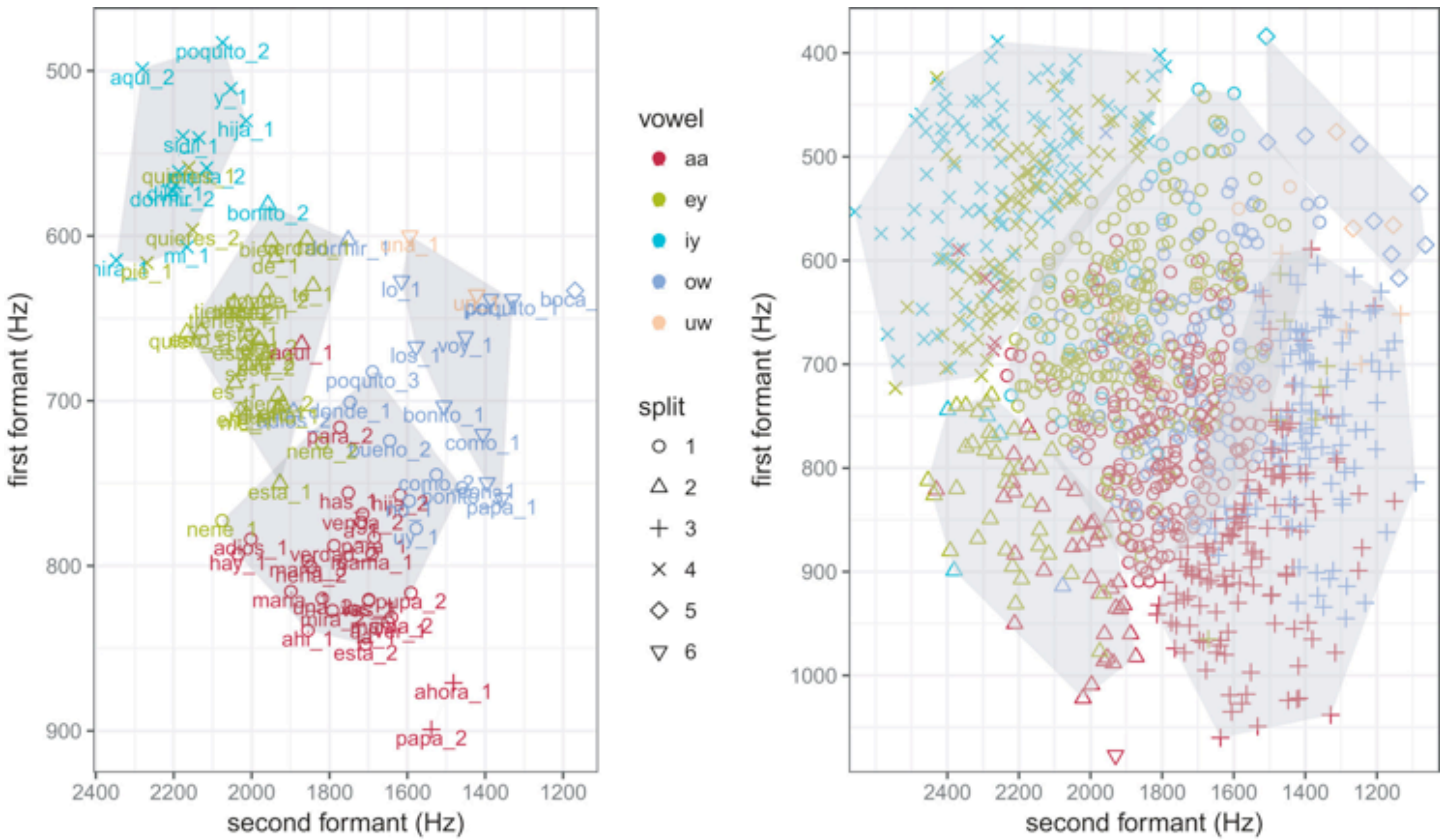
Vowels /i/ (blue) and /ɪ/ (red) in a corpus. Outlined tokens are from the words *see* (circles), *we* (triangles), *Dillon* (squares) and *this* (diamonds) (Swingley, 2009)

Collapsing phonetic observations to word type averages reduces variability



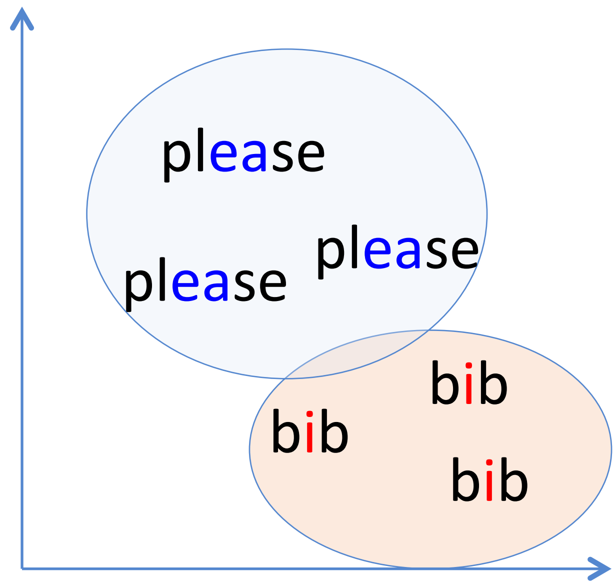
F1 and F2 of vowels in Spanish words with a corpus frequency of 5 or more (Swingley & Alarcon ,2018)

Word-type analysis is more accurate than token-based analysis of categories



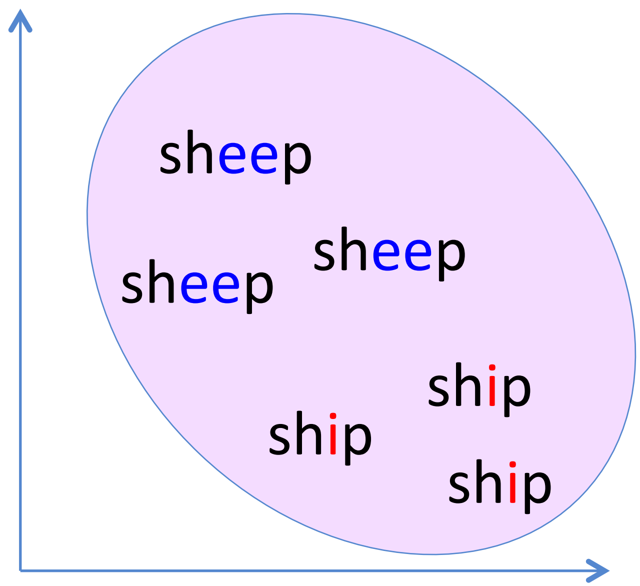
Assignment of Spanish vowels to categories based on words (left) and tokens (right) (Swingley & Alarcon, 2018)

This works only when the words with the critical contrast are sufficiently distinct



Non-minimal pair for /i-ɪ/

One word with phonetic variation?



Minimal pair for /i-ɪ/

In fact, infants learn to distinguish sounds (only) if they occur in *non-minimal pairs*

	Familiarization		Test (Discriminate /ɑ/-/ɔ/)?
Minimal pair condition	*Gutah* *Gutaw* *Litah* *Litaw*	→	NO
Non-minimal pair condition	*Gutah* *Litaw* OR *Gutaw* *Litah*	→	YES

8-month-olds' learning of vowel contrast after exposure to novel word tokens (Feldman, Myers, et al. 2013)

Summary

- Infants acquire native contrasts and a receptive lexicon around the same time (6-10 months). But few minimal pairs are available then.
- Sound categories can be learned without lexical information through DL from phonetic input, but the utility of DLfPI is limited for certain contrasts (e.g., vowel length/quality).
- Phonetic learning needs to be augmented by lexical information (of *non-minimal* pairs) to successfully derive sound categories.