LSci 51/Psych 56L: Acquisition of Language

Lecture 9

Phonological development II

Announcements

Be working on the review questions for phonological development

Be working on HW3 (due 8/22/25)

Speech perception

Speech production processes must be *undone* by the ear

Motions of articulators must be *reconstructed* from patterns of air vibration

Requires extremely precise hearing, possibly a system specialized for hearing speech

Substantially developed at birth

Prelinguistic speech perception

Infant hearing

Infant hearing isn't quite as sensitive as adult hearing…

Example: Newborns (Arenillas-Alcón, Costa-Faidella, Ribas-Prats, Gómez-Roig, & Escera 2021)

"Newborn neural encoding of voice pitch is comparable to the adults' abilities after three years of being exposed to language. However, there are differences regarding the perception of spectral and temporal fine structures of sounds, which consists on the ability to distinguish between vocal sounds such as /o/ and /a/."

https://www.sciencedaily.com/releases/2021/04/210426111601.htm

Infant hearing

Infant hearing isn't quite as sensitive as adult hearing - but they *can* hear quite well and remember what they hear.

Example: Fetuses 8 months old

(Minai, Gustafson, Fiorentino, Jongman, & Sereno 2017)

A fetal biomagnetometer was used to measure fetal heart rate in English babies-to-be in response to a bilingual speaker speaking either English or Japanese. Fetal heart rates changed when they heard the unfamiliar, rhythmically distinct language (Japanese) after having heard a passage of English speech, while their heart rates did not change when they were presented with a second passage of English instead of a passage in Japanese.

https://www.sciencedaily.com/releases/2017/07/170718084600.htm

Infant hearing

Infant hearing isn't quite as sensitive as adult hearing - but they *can* hear quite well and remember what they hear.

Example: Fetuses 38 weeks old

A loudspeaker was placed 10cm away from the mother's abdomen. The heart rate of the fetus went up in response to hearing a recording of the mother's voice, as compared to hearing a recording of a stranger's voice.

Infant hearing

Infant hearing isn't quite as sensitive as adult hearing - but they *can* hear quite well and remember what they hear.

Example: Newborns

Pregnant women read a passage out loud every day for the last 6 weeks of their pregnancy. Their newborns showed a preference for that passage over other passages read by their mothers.

Infant hearing

Infant hearing isn't quite as sensitive as adult hearing - but they *can* hear quite well and remember what they hear.

Example: Newborns (Moon, Lagercrantz, & Kuhl 2012)

Swedish and English newborns heard different ambient languages while in the womb (Swedish and English, respectively), and were surprised when they heard non-native vowels only hours after birth.

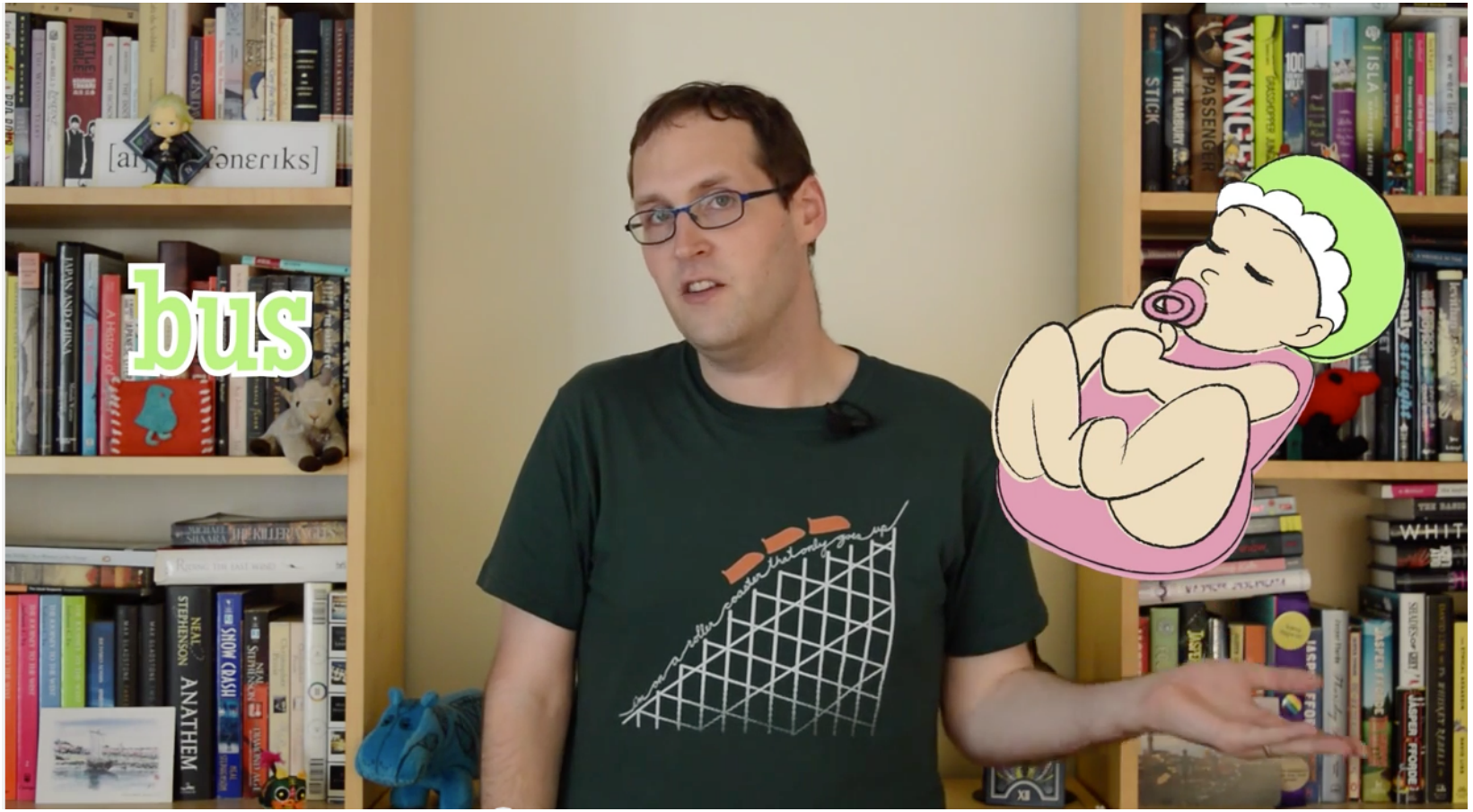
[Extra]

Studying infant speech perception

http://www.thelingspace.com/episode-16

https://www.youtube.com/watch?v=3-A9TnuSVa8

beginning through 3:34: High Amplitude Sucking Procedure (HAS)



[Extra]

Studying infant speech perception

http://www.thelingspace.com/episode-16

https://www.youtube.com/watch?v=3-A9TnuSVa8

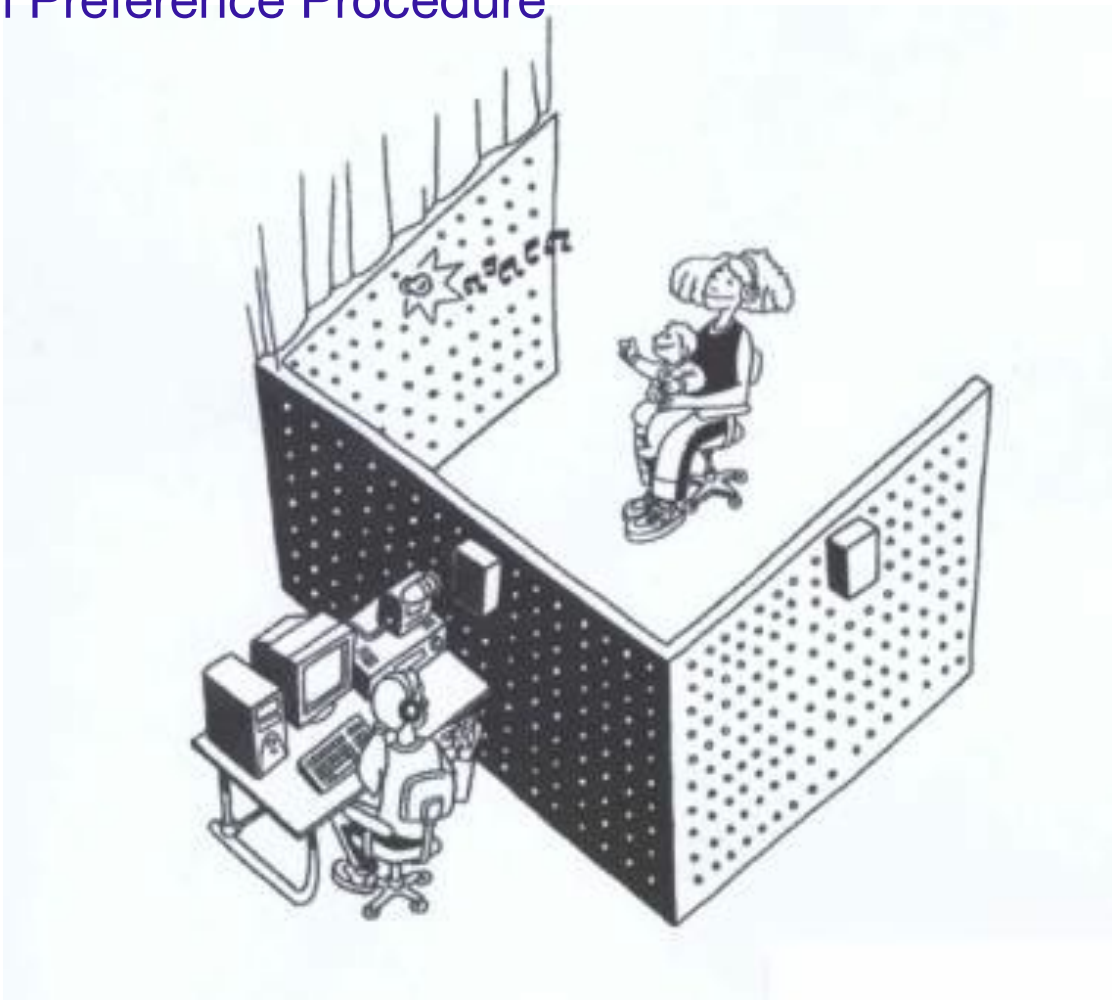
3:34 - 5:48: Head-Turn Preference Procedure

[Extra]

Studying infant speech perception

Researchers use indirect measurement techniques.

Head-Turn Preference Procedure



[Extra]

Studying infant speech perception

Researchers use indirect measurement techniques.

Head-Turn Technique

https://www.youtube.com/watch?v=WvM5bqUsbu8
Especially 0:31-1:15

Categorical perception

One feature of infants' speech perception: categorical perception.

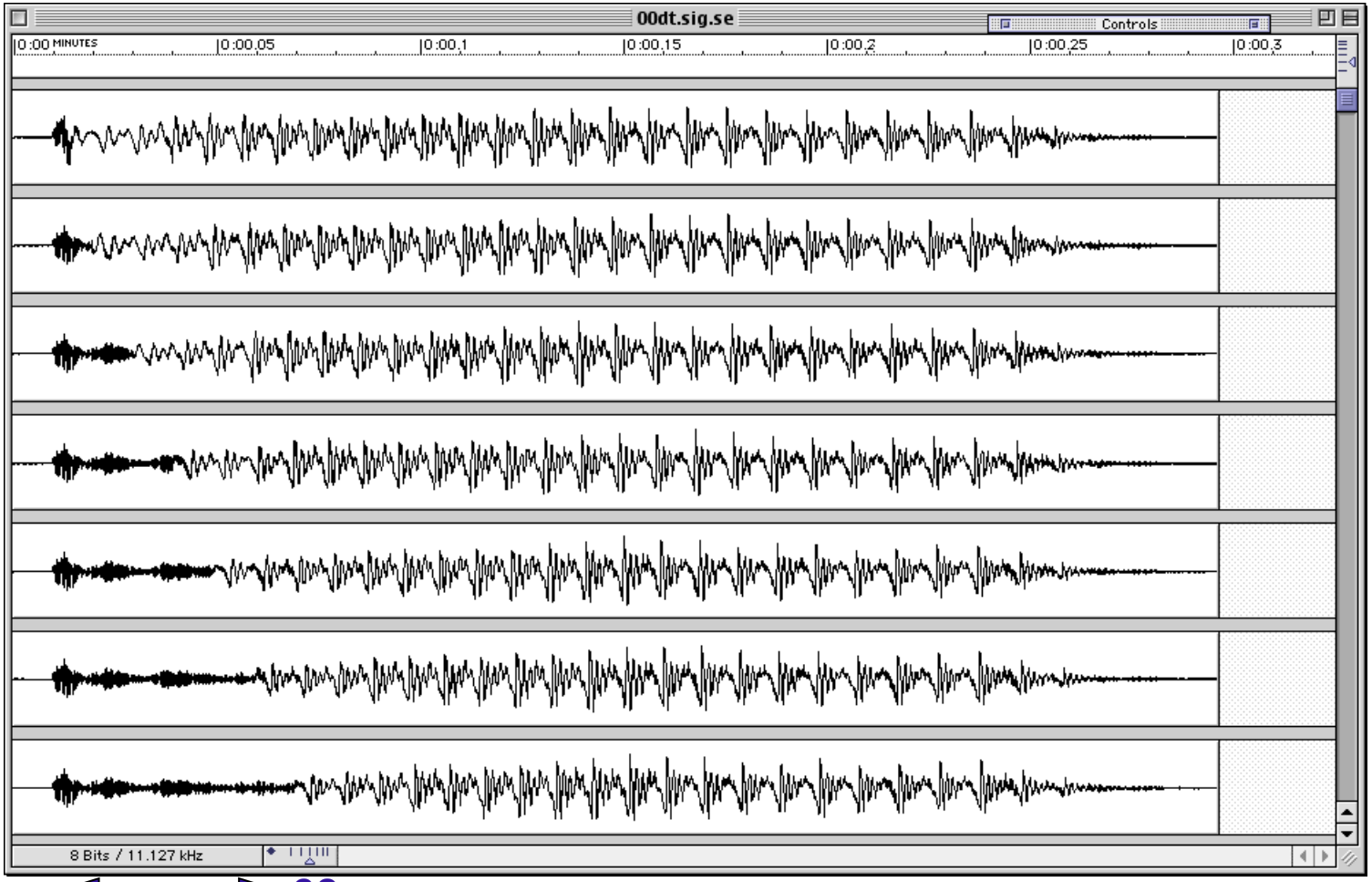
Categorical perception occurs when a range of stimuli that differ continuously are perceived as belonging to only a few categories with no degrees of difference within those categories.

Actual stimuli

Perception of stimuli

Categorical perception

Adult categorical perception: Voice Onset Time (VOT)



English VOT production

Not uniform - there are 2 categories (distribution is bimodal)

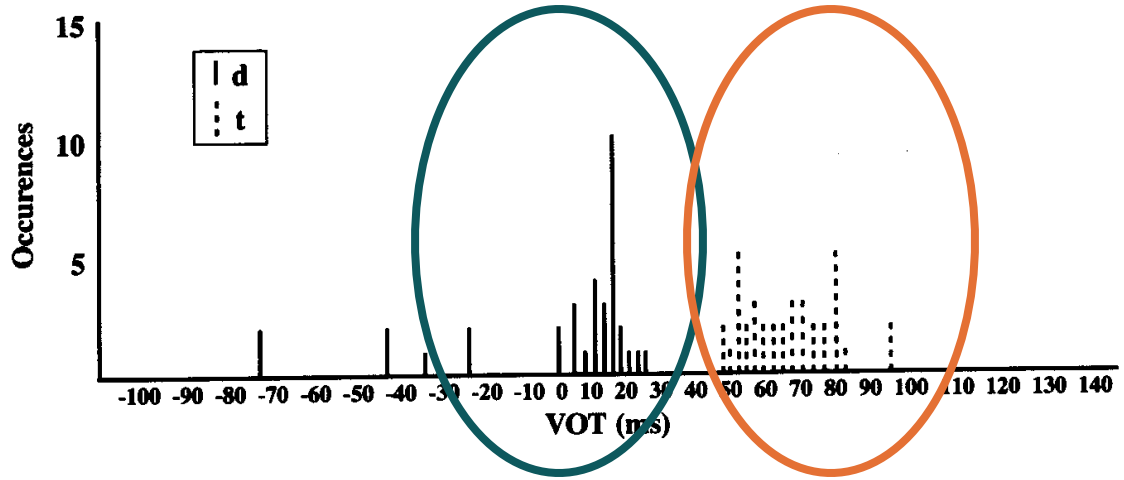
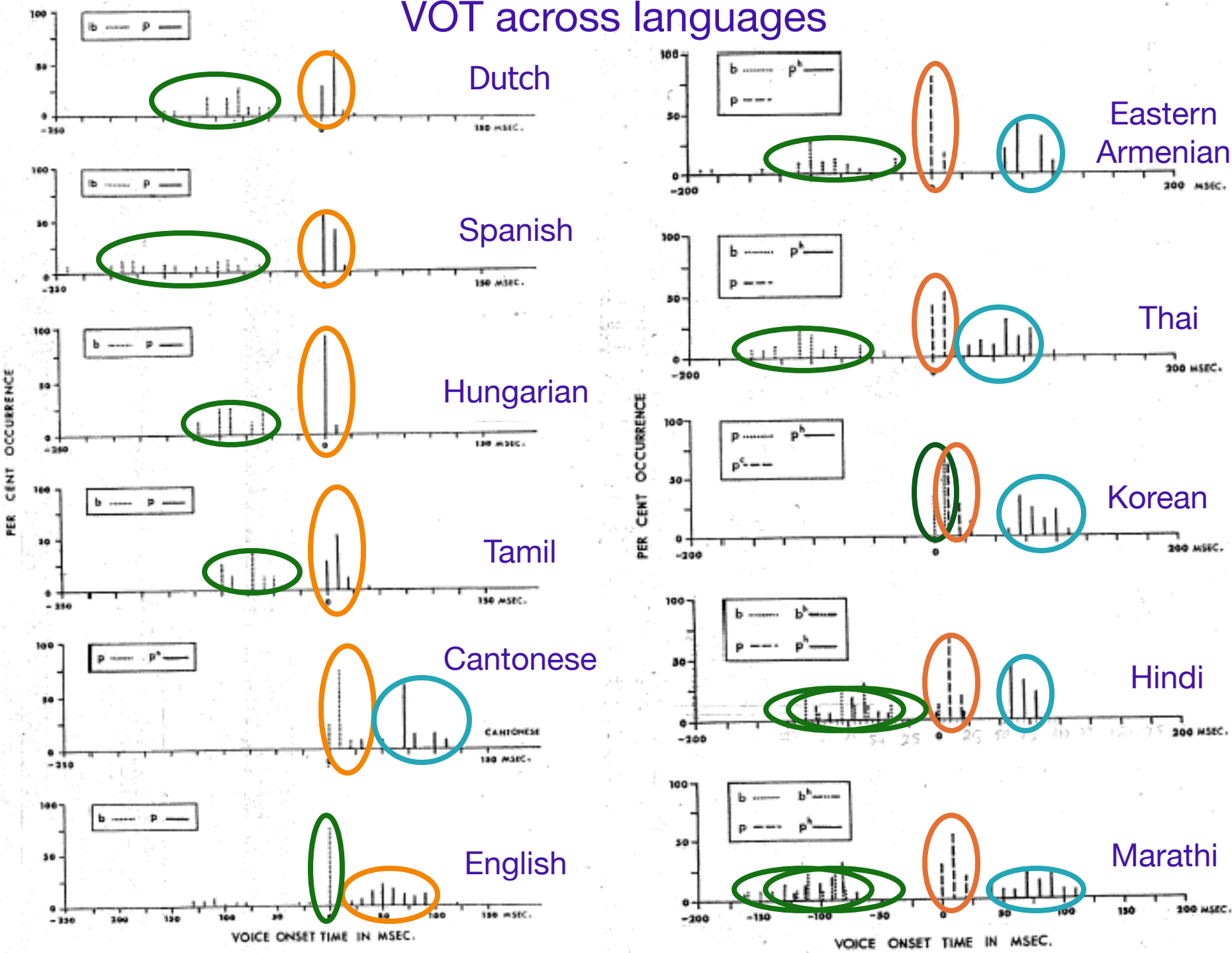


Figure 5–3. VOT productions of a single normal adult speaker of American English for words beginning with /d/ and /t/. (Figure adapted with permission from Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, [1980]. Production Deficits in Aphasia: A Voice Onset-Time Analysis. *Brain and Language, 9*, 153–170. Copyright 1980 by Academic Press.)

Perception of stimuli: 2 categories

VOT across languages



Perceiving VOT:
Forced Choice Identification Task

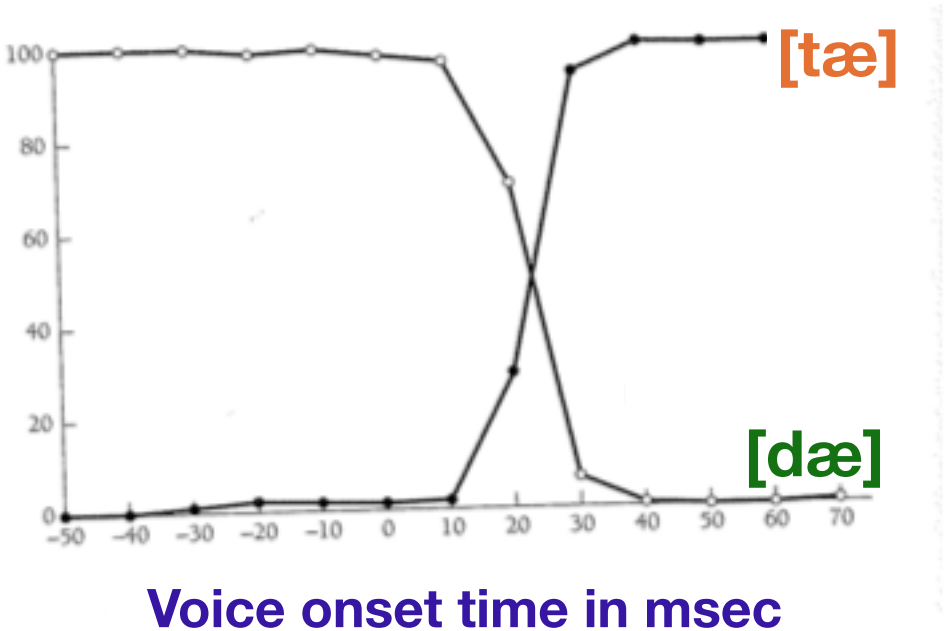
Forced choice identification is one common way to test for categorical perception: Have people listen to many examples of speech sounds and indicate which one of two categories each sound represents. (This is a two-way forced choice.)

Ex: “Is this sound a /dæ/ or a /tæ/?”

Perceiving VOT:
Forced Choice Identification Task

Adult categorical perception: Voice Onset Time (VOT)

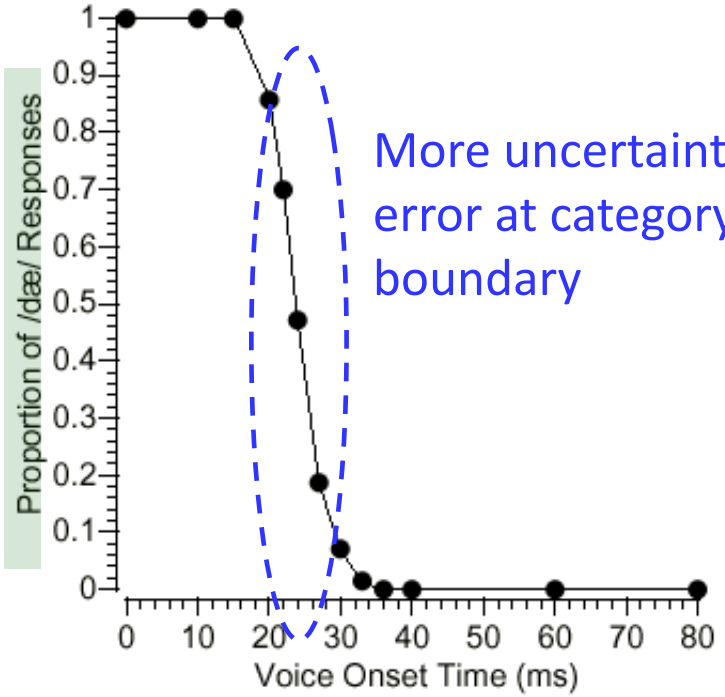
% of responses as either /dæ/ or /tæ/



Even though the sounds change acoustically, it seems easy to decide which kind of sound is being heard, except in a few cases.

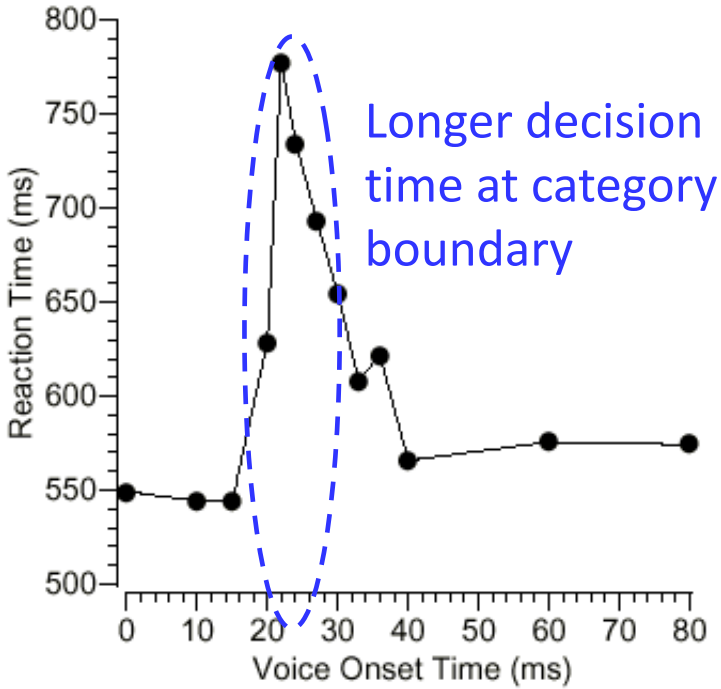
Perceiving VOT:
Forced Choice Identification Task

Categorical Perception: /dæ/ vs. /tæ/



More uncertainty/ error at category boundary

Decision between d/t



Longer decision time at category boundary

Time to make decision

Identification task:"Is this sound /dæ/ or /tæ/ ?"

Categorical perception

Adult categorical perception: Voice Onset Time (VOT)

Within-category discrimination is hard,
across-category discrimination is easy

D	0ms	20ms	D
D	20ms	40ms	T
T	40ms	60ms	T

Cross-language differences

R L

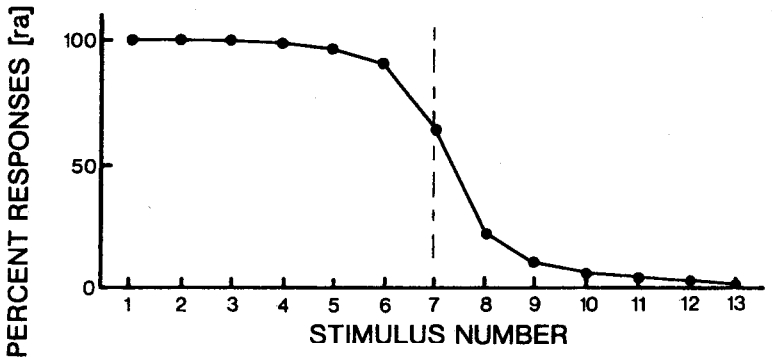
R L

Cross-language differences

Identification task:
“Which sound is this?”

English speakers can discriminate r and l, and seem to show a similar pattern of categorical perception to what we saw for d vs. t

Miyawaki et al. 1975



R ----------> L

Cross-language differences

Discrimination task: “Are these sounds the same or different?”

English speakers have higher performance at the r/l category boundary, where one sound is perceived as r and one sound is perceived as l.

Miyawaki et al. 1975

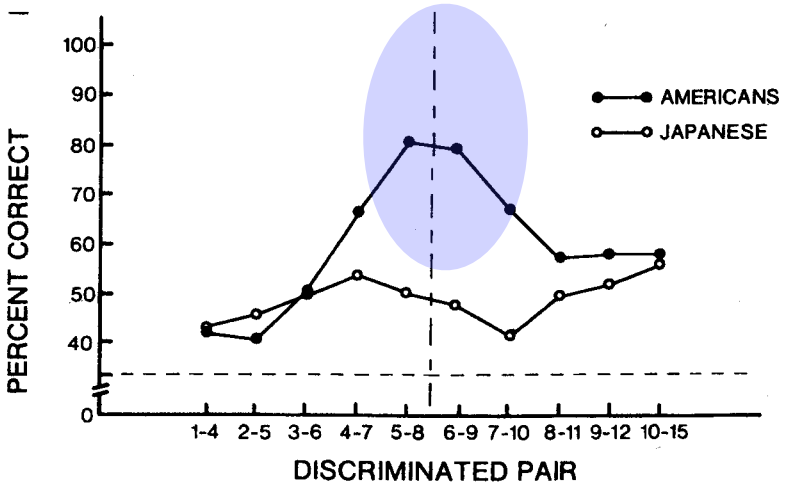


Figure 12.2. Test of the categorical perception of /ra/ and /la/ by American and Japanese adults. American listeners show the characteristic peak in discrimination at the phonetic boundary; Japanese listeners do not. (From Miyawaki et al., 1975.)

Cross-language differences

Discrimination task: “Are these sounds the same or different?”

Japanese speakers generally perform poorly (at chance), no matter what sounds are compared because r and l are not contrastive for them.

Miyawaki et al. 1975

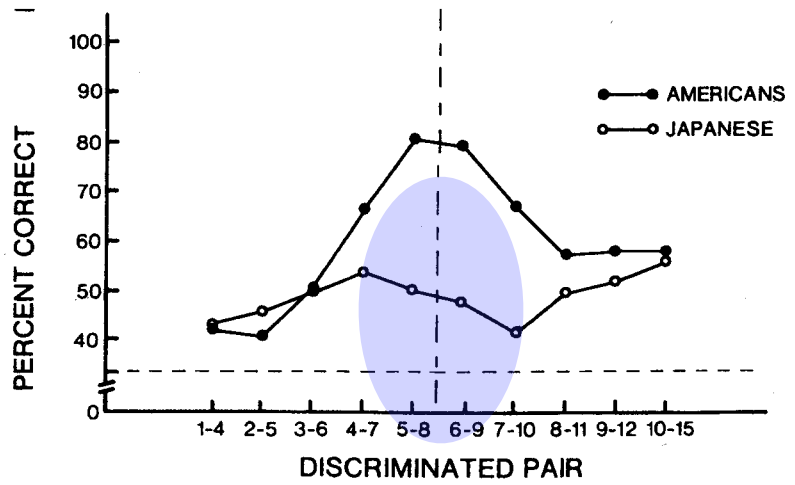


Figure 12.2. Test of the categorical perception of /ra/ and /la/ by American and Japanese adults. American listeners show the characteristic peak in discrimination at the phonetic boundary; Japanese listeners do not. (From Miyawaki et al., 1975.)

Cross-language differences

Hindi

dental [d]

(tip of tongue touches back of teeth)

?

retroflex [D]

(tongue curled so tip is behind alveolar ridge)

English [d] is usually somewhere between these

Cross-language differences

Salish
(Native North American language):
glotalized voiceless stops

Uvular – tongue is raised behind the velum

Velar – tongue is raised against the velum

(they are actually ejectives - ejectives are produced by obstructing the airflow and raising to glottis to increase pressure)

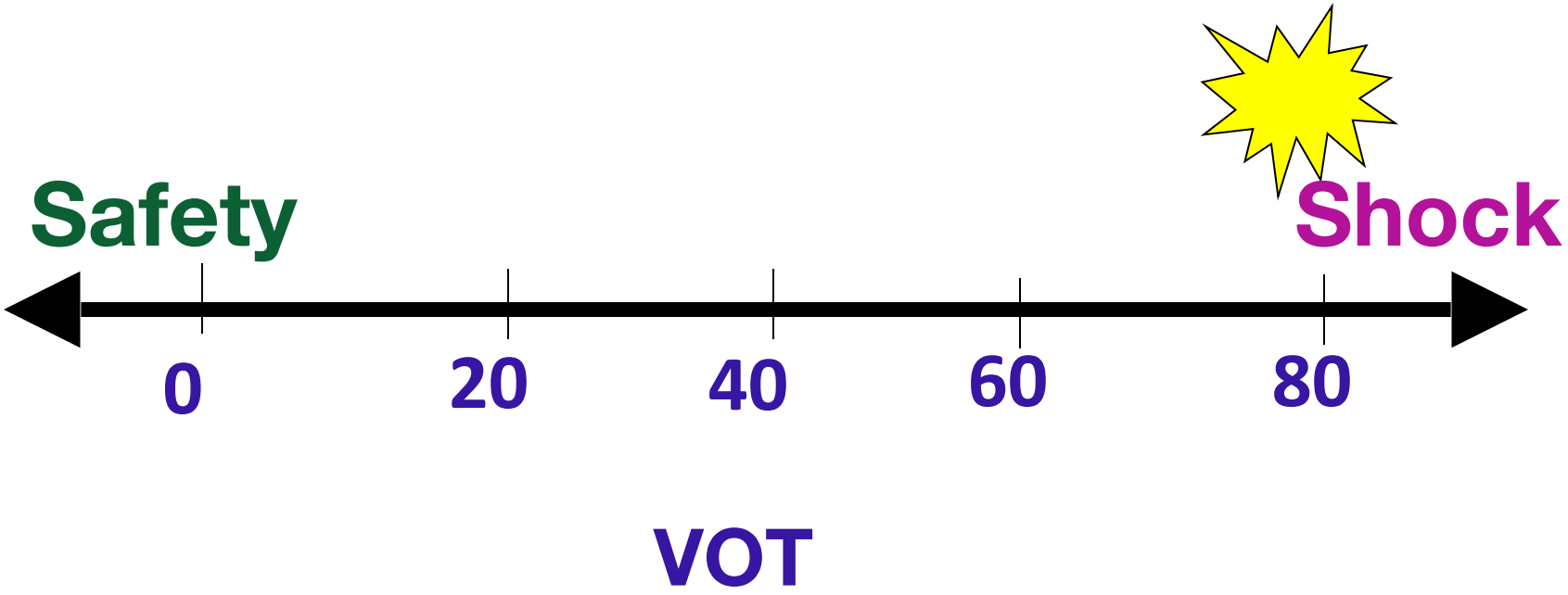
Categorical perception

Categorical perception: a special human ability?

Categorical perception is not specific to the human ear, though - it's a feature shared with other mammals like chinchillas (tested with an **Avoidance Conditioning Procedure**)!

Avoidance conditioning procedure

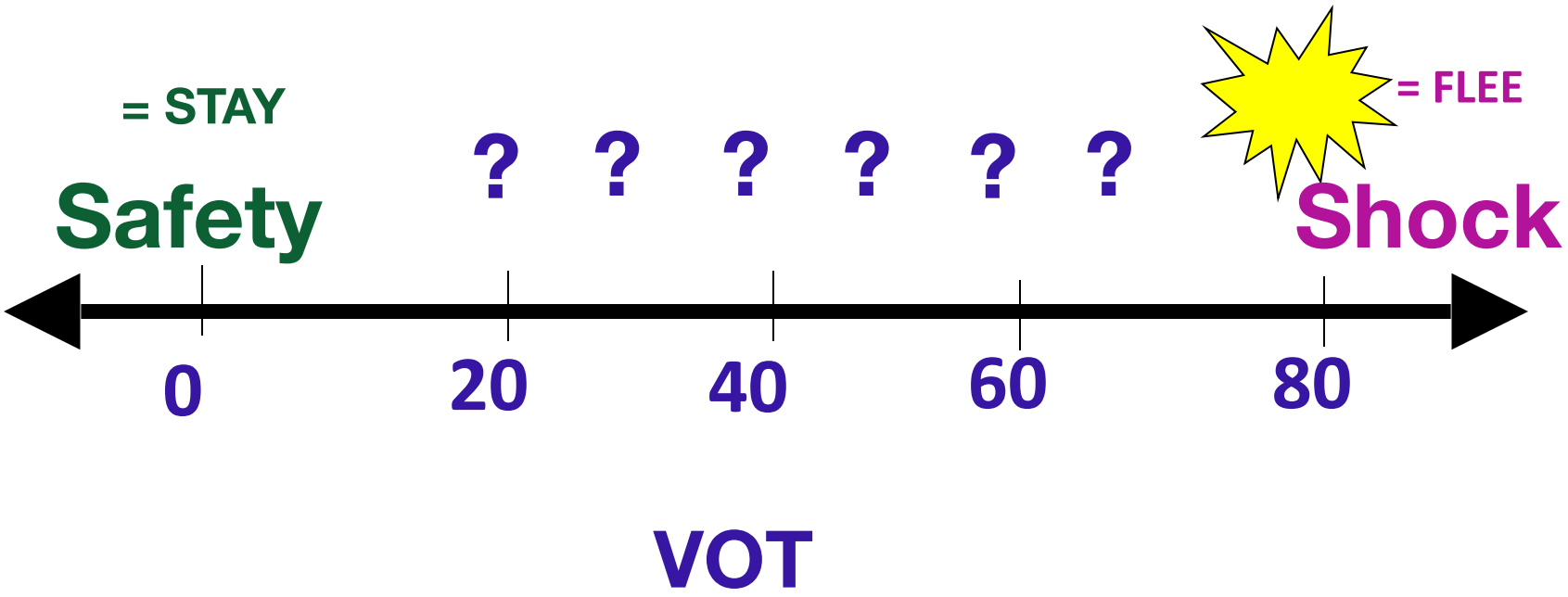
- Speech sound at one end of the continuum paired with shock
- Other end paired with safety



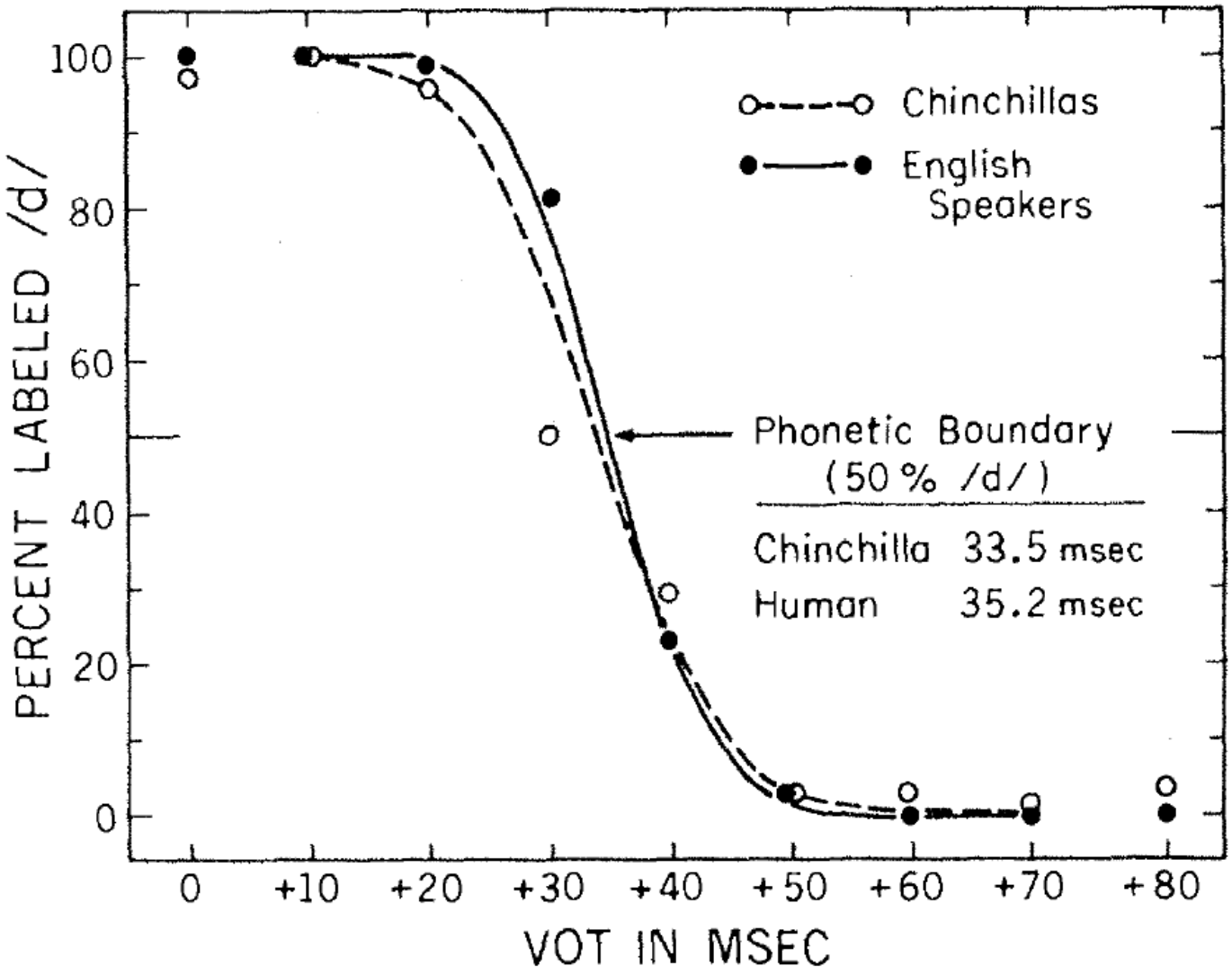
Avoidance conditioning procedure

Animals learn to “avoid” shock.

What will they do for between cases?



Kuhl & Miller (1978)



Why categorical perception is so helpful: The lack of invariance problem

"…no two utterances of a particular phoneme—for example, the /p/ in *pick*—are identical….might sometimes produce her /p/ sound with a VOT of 70 ms, sometimes with a VOT of 90 ms….might produce /p/ with relatively shorter VOTs….[or] pronounce the sound with longer VOTs. Add to that the fact that the sounds abutting the /p/ will bleed into the consonant; the /p/ sound in *pick*, for example, is acoustically different from the /p/ sound in *poke*. An infinite number of acoustic patterns can map into a single speech sound."

- Myers 2017, on the lack of invariance problem

Why categorical perception is so helpful: The lack of invariance problem

"…To convince yourself of how difficult it can be to translate acoustic cues into words, try any commercially available speech-recognition interface such as Apple's Siri or Amazon's Alexa. Say a single, monosyllabic word such as *pack* clearly and slowly, and the system is reasonably likely to identify it correctly. However, if you repeat the word *pack* quickly, you may get a multitude of responses; in different tries, Siri thought I was saying *back*, *beck*, *talk*, and *part*."

- Myers 2017, on the lack of invariance problem

Why categorical perception is so helpful: The lack of invariance problem

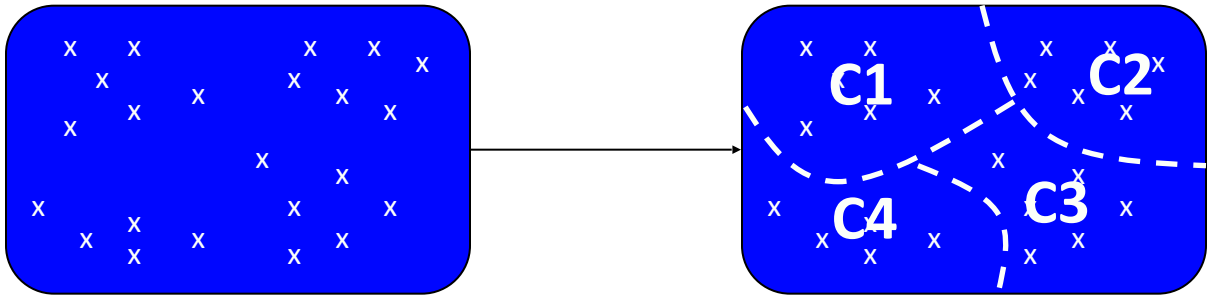
"….the human speech system does not deliver the entire auditory content to the point of conscious awareness. Rather, we usually can perceive only acoustic differences that matter for meaning…may be in place to help our brain's limited resources focus on only the most important aspects of the speech signal."

- Myers 2017, on the utility of categorical perception

Speech perception: The problem

Divide sounds into contrastive categories (phonemes)

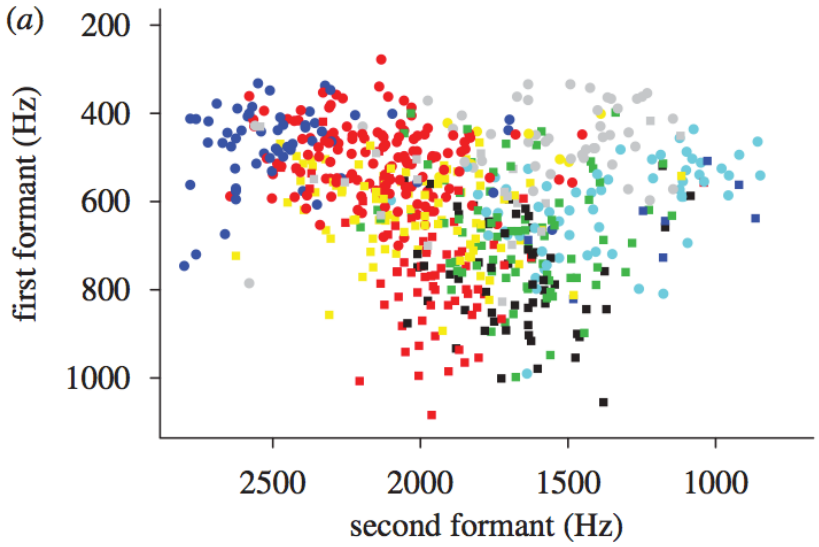
Here, 23 acoustically-different sounds are clustered into 4 contrastive categories.



Speech perception: The problem

Note:

Real life sounds are actually much harder because categories overlap.

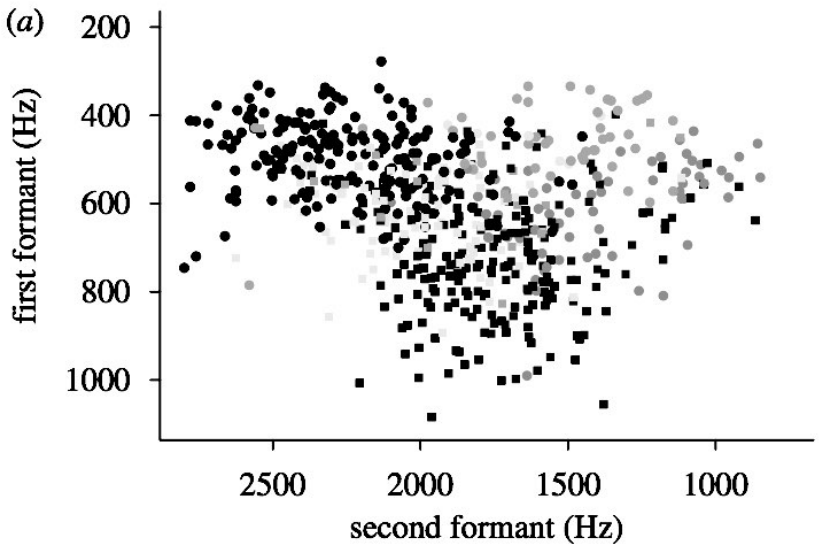


Each color represents one vowel (that is, a sound perceived by native speakers as one vowel, like “oo” or “ee”).

Speech perception: The problem

Note:

Real life sounds are actually much harder because categories overlap.

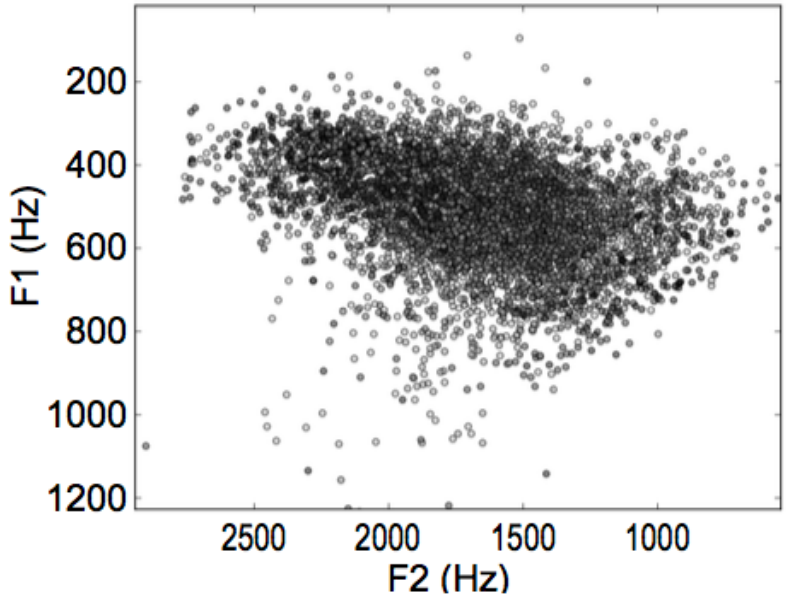


If you didn't know beforehand that this is how the sounds were divided out, it would be really hard to tell what category a sound belonged to!

Speech perception: The problem

Note:

Real life sounds are actually much harder because categories overlap.



Another real life example of overlapping sounds

How do kids learn the contrastive sound categories for their language?

[Extra]

Categorical perception

http://www.thelingspace.com/episode-4

https://www.youtube.com/watch?v=dtf8zGQj9GY

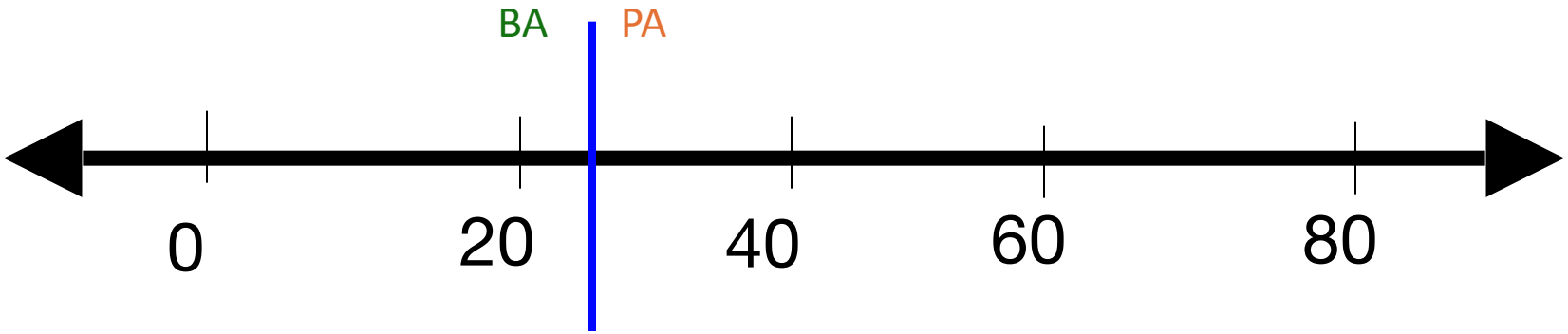
5:39-6:59

Infants start off early with categorical perception abilities

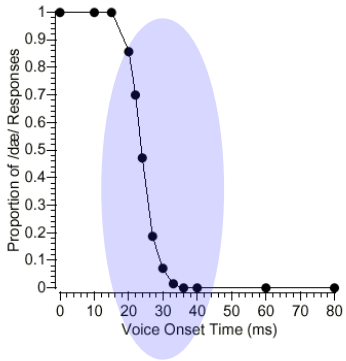
Eimas et al. 1971: HAS technique with 4-month-olds

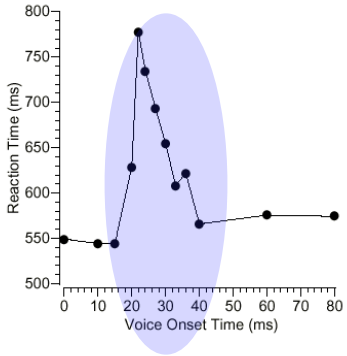
- BA vs. PA
- Vary VOT: time between consonant release and vocal cord vibration

English adult category boundary



VOT in milliseconds

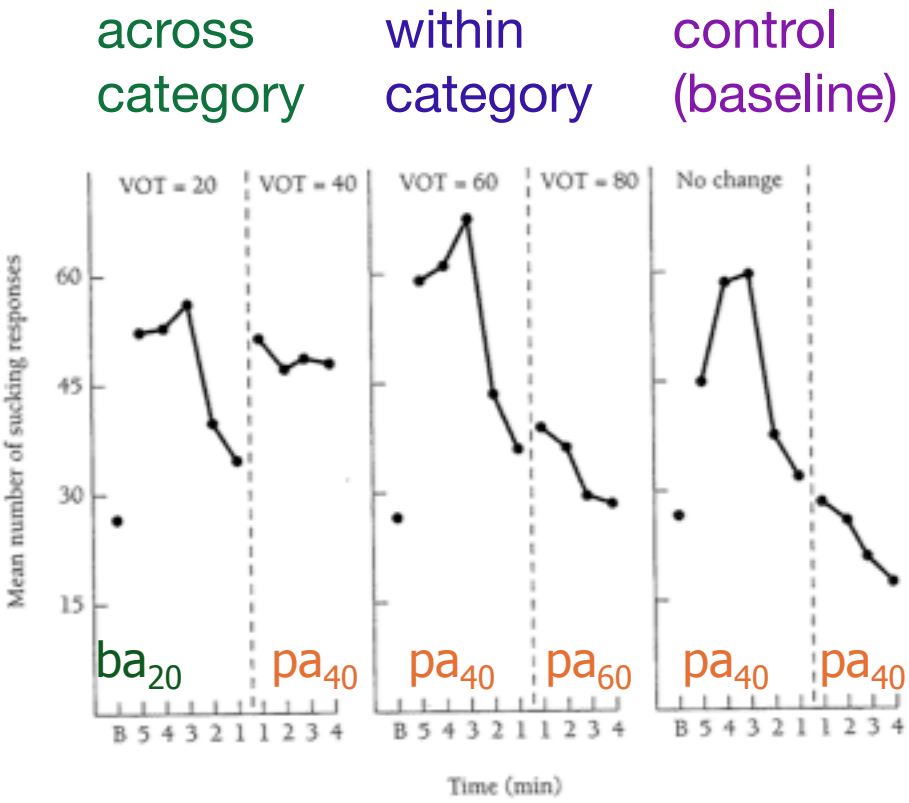




Infants start off early with categorical perception abilities

Infant categorical perception: Voice Onset Time (VOT)

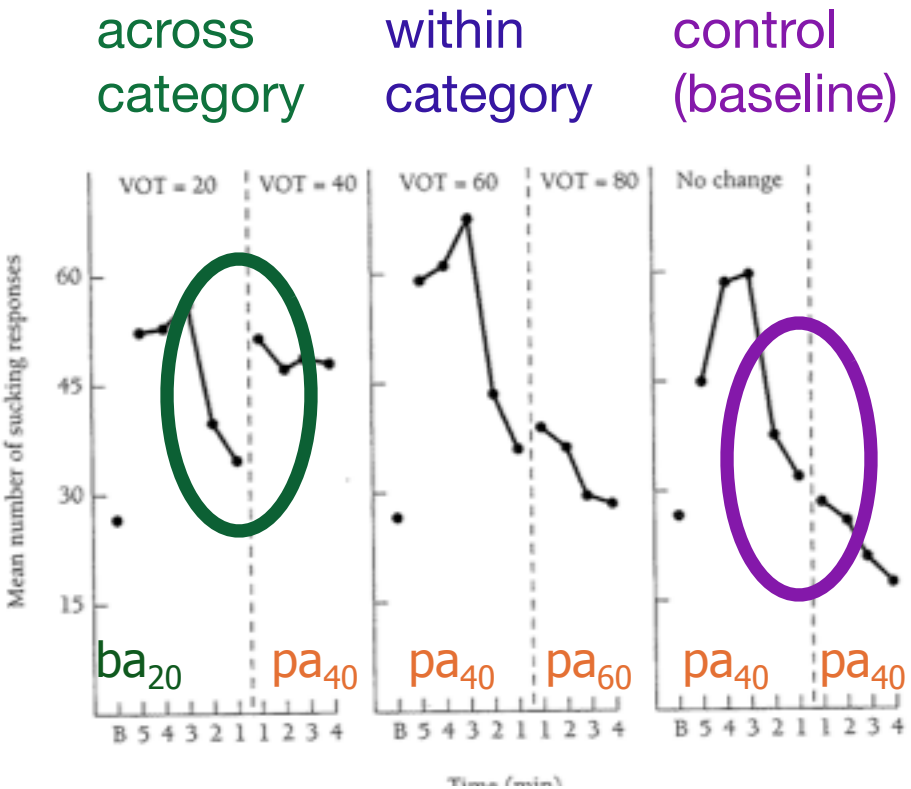
Eimas et al. 1971: HAS technique



Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique

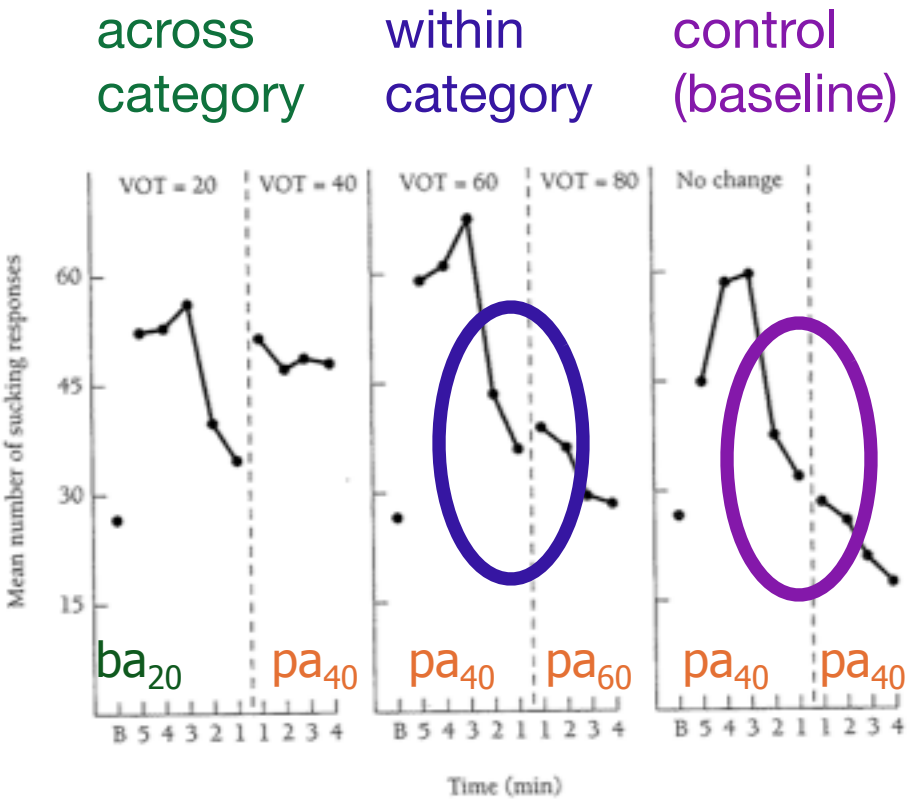


Infants notice, compared to control

Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique

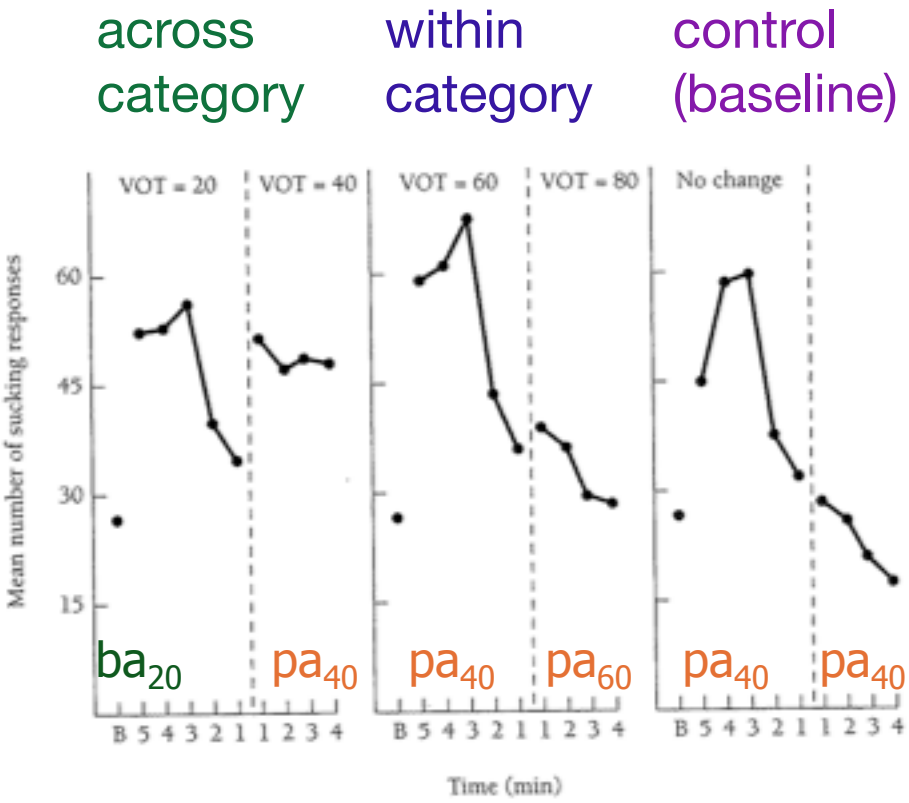


Infants don't notice, compared to control

Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique



Upshot: Infants are sensitive to this category boundary at 4 months

Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

What about other contrasts? (Especially ones that aren't going to be useful in the language they're learning)

Speech perception of non-native sounds

Werker et al. 1981: English-learning 6-8 month olds compared against English & Hindi adults on 2 Hindi contrasts

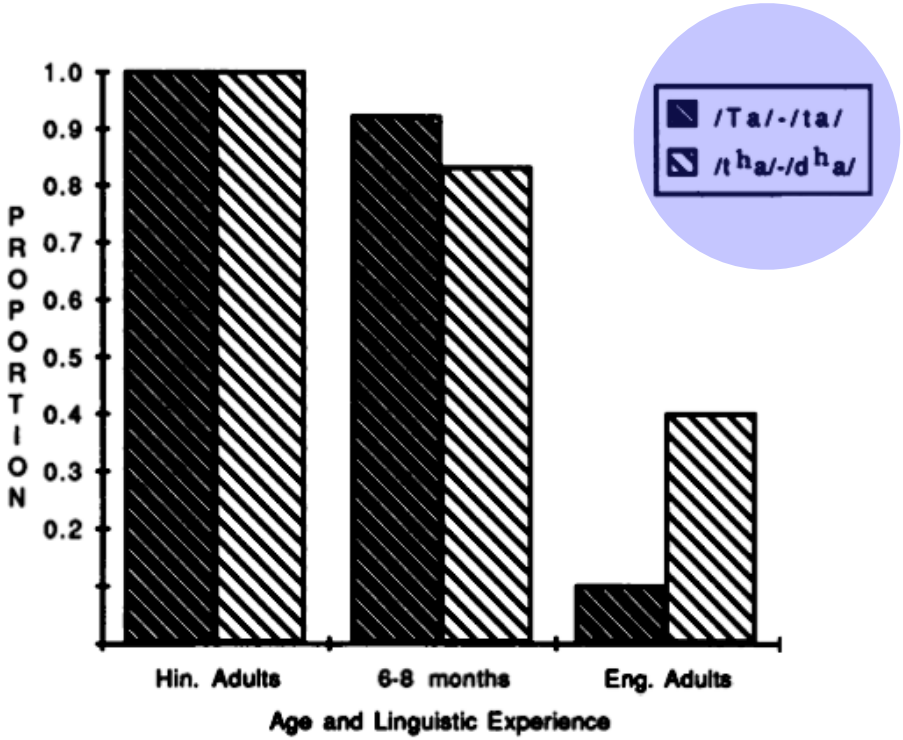


Figure 4.2
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

Speech perception of non-native sounds

Werker et al. 1981: English-learning 6-8 month olds compared against English & Hindi adults on Hindi contrasts

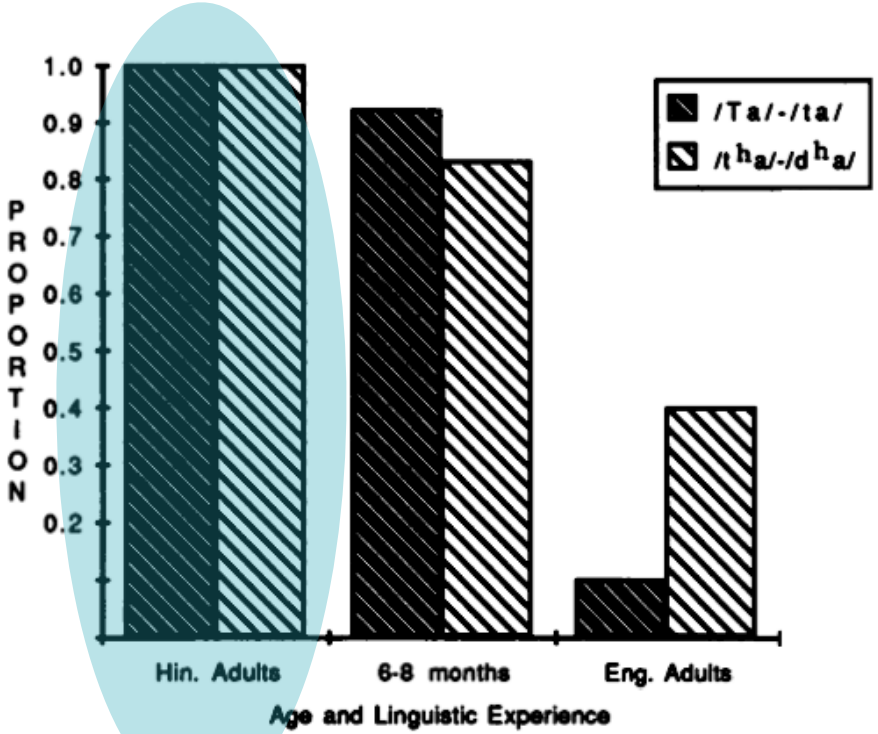


Figure 4.2
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

Control:
Hindi adults can easily distinguish sounds that are used contrastively in their language

Speech perception of non-native sounds

Werker et al. 1981: English-learning 6-8 month olds compared against English & Hindi adults on Hindi contrasts

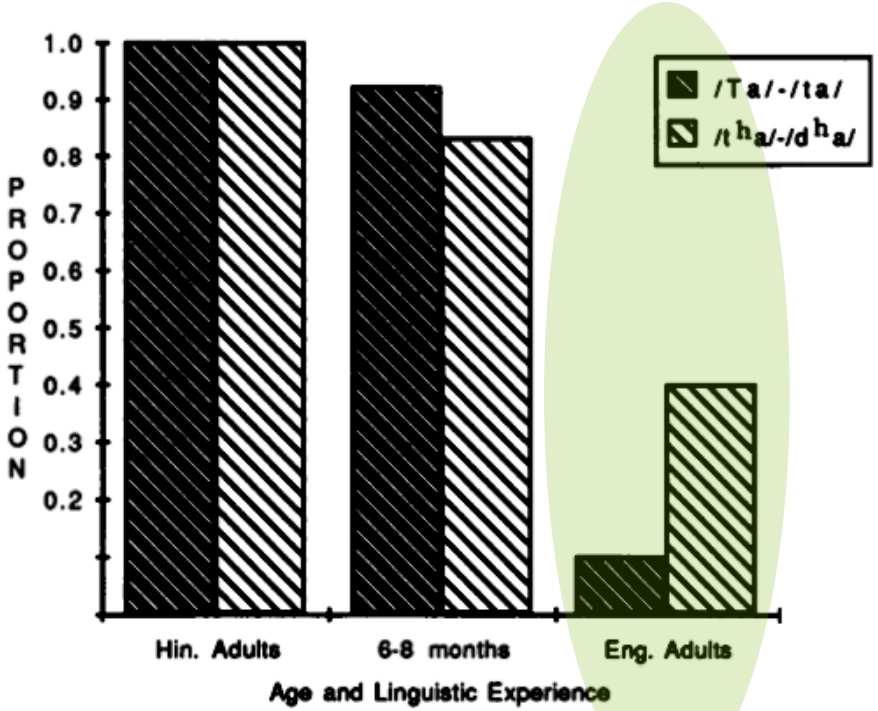


Figure 4.2
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

Control:
English adults are terrible (below chance), though there is some variation depending on which sounds are being compared

Speech perception of non-native sounds

Werker et al. 1981: English-learning 6-8 month olds compared against English & Hindi adults on Hindi contrasts

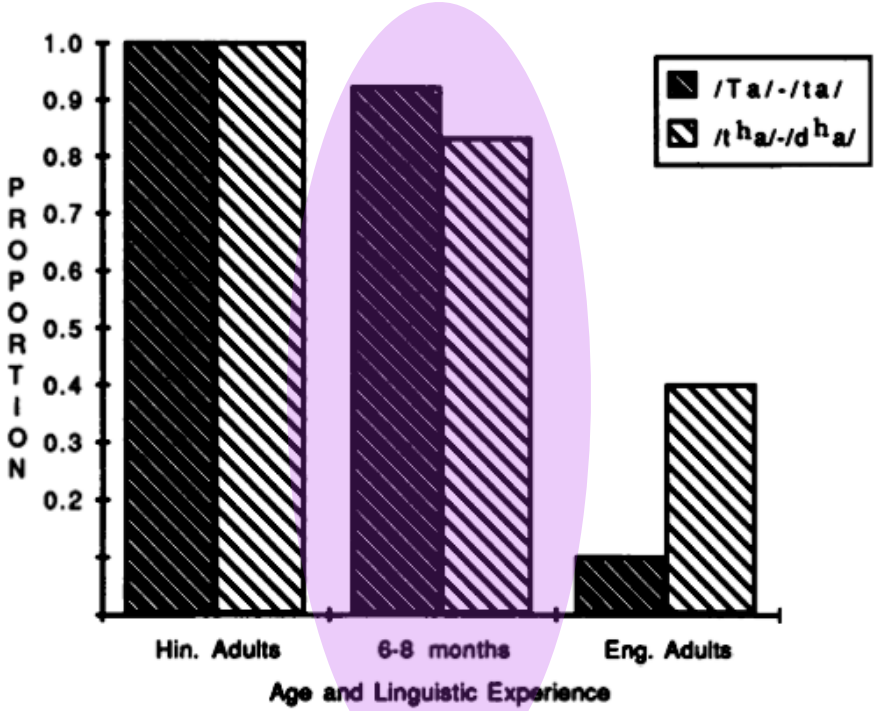


Figure 4.2
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

What about English infants?

English infants between the ages of 6-8 months aren't quite as good as Hindi adults - but they're certainly much better than English adults!

Speech perception of non-native sounds

Werker et al. 1981: English-learning 6-8 month olds compared against English & Hindi adults on Hindi contrasts

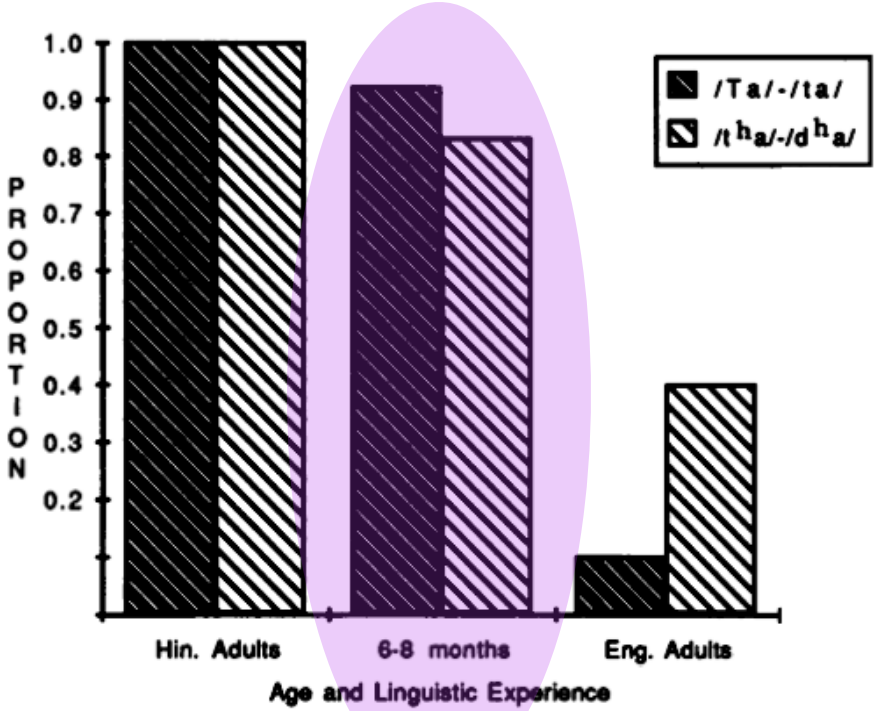


Figure 4.2
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

What about English infants?

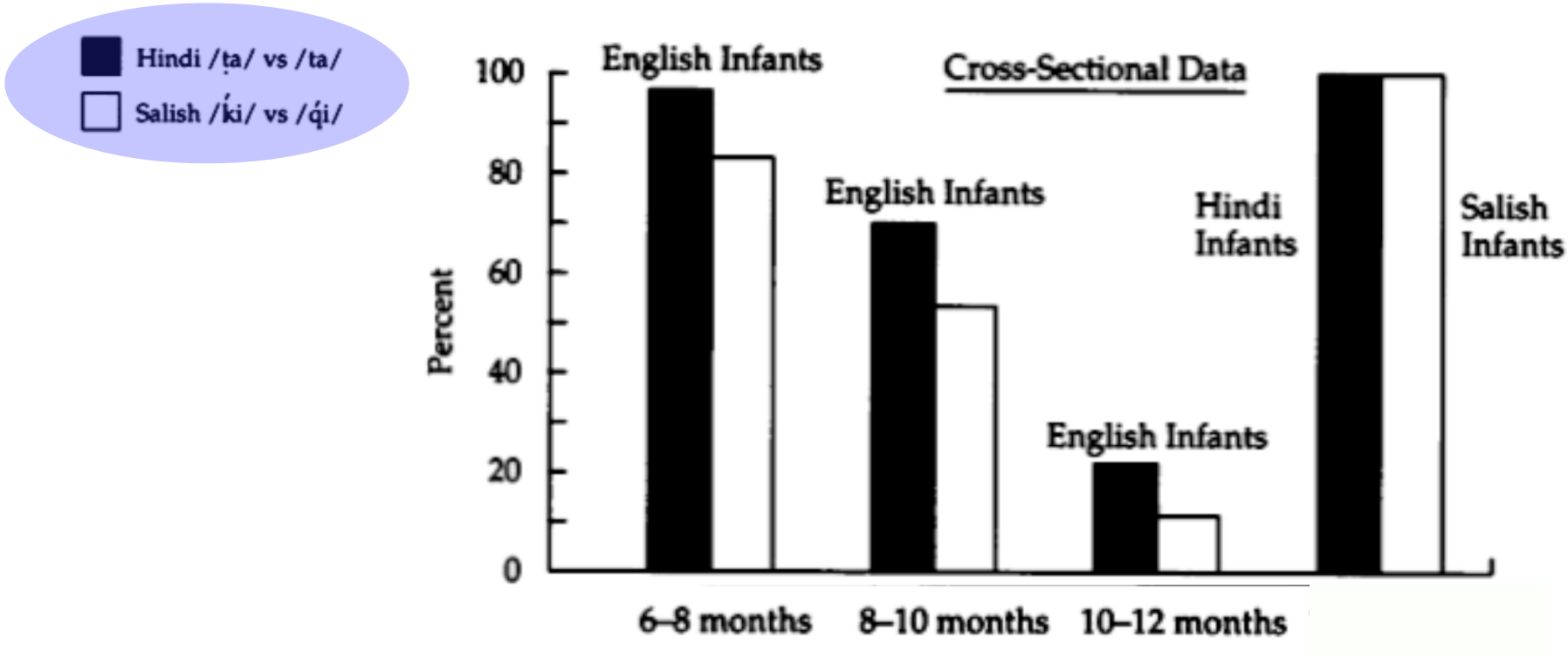
One interpretation:

They haven't yet learned to ignore these non-native contrasts.

When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

Testing ability to distinguish
Salish & Hindi contrasts



When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

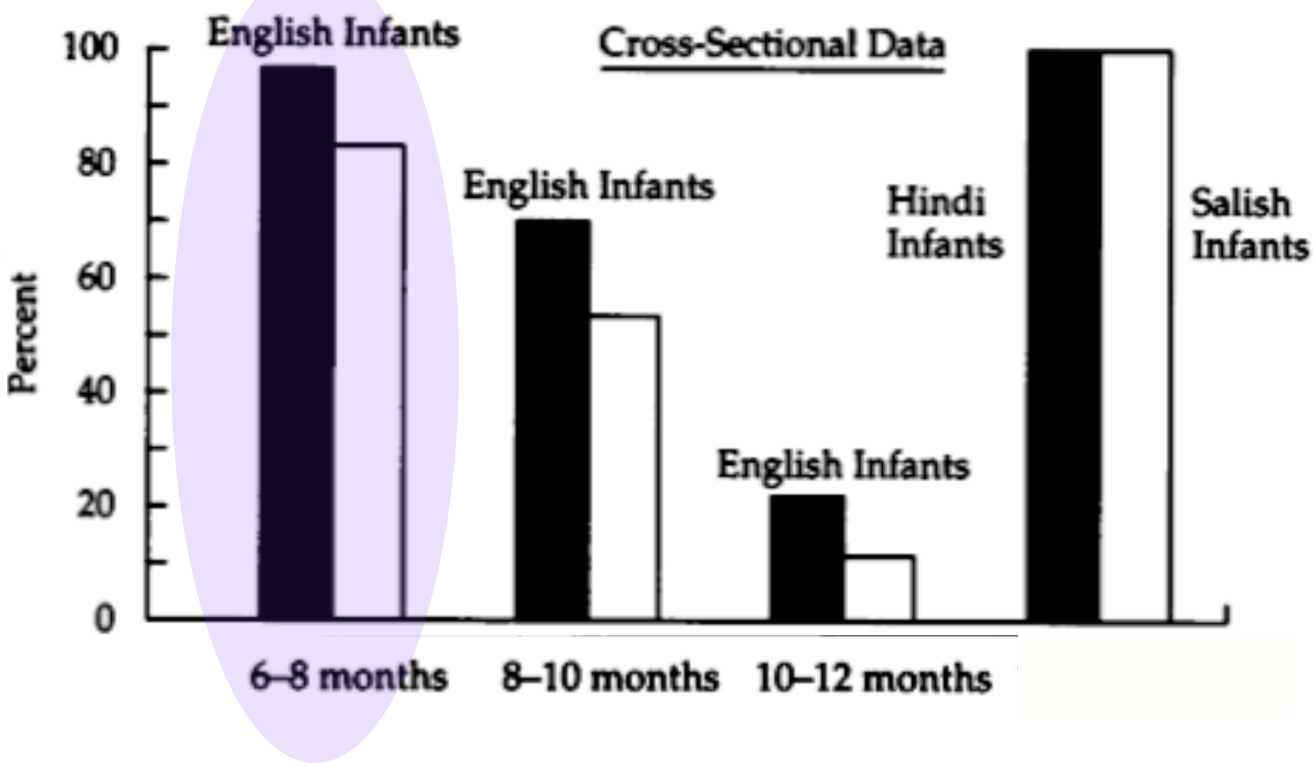
Testing ability to distinguish
Salish & Hindi contrasts

Control (make sure experiment is doable by infants):
Hindi and Salish infants do perfectly

When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

Testing ability to distinguish
Salish & Hindi contrasts

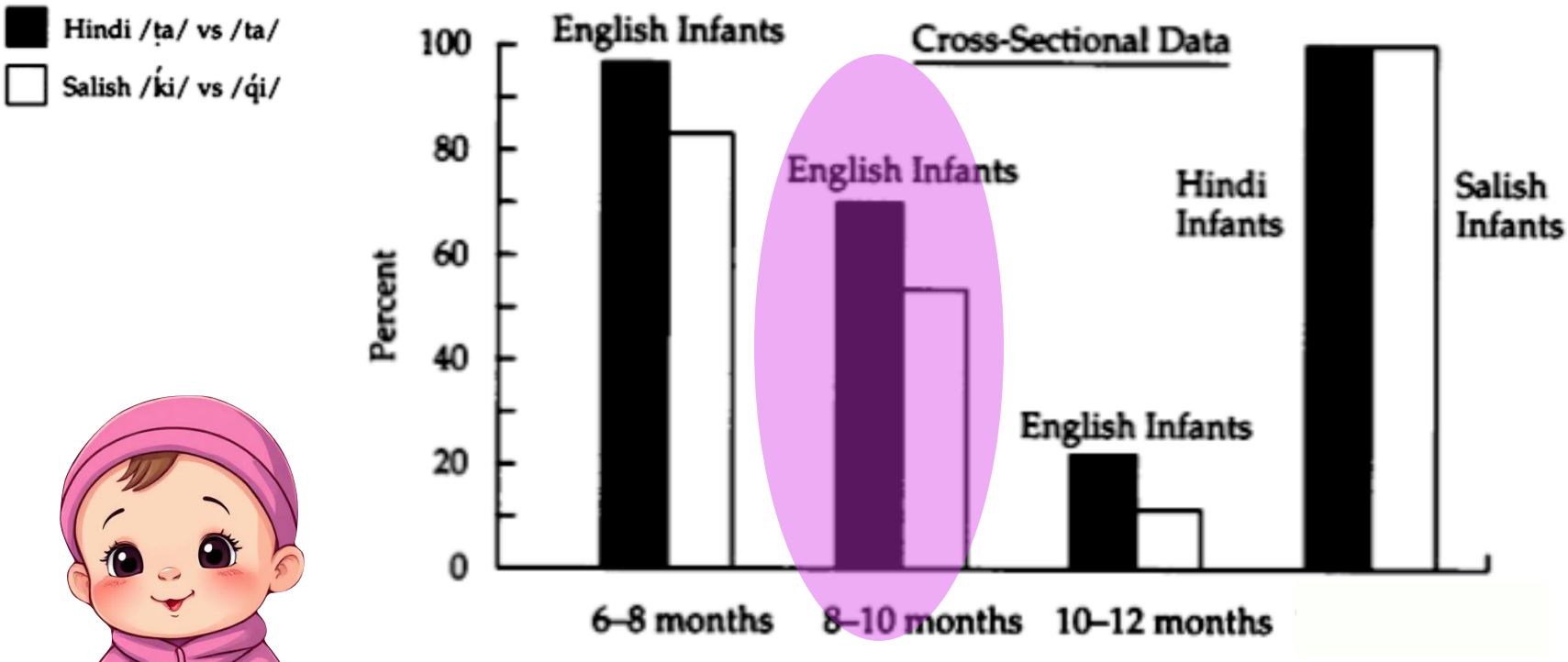


English 6 to 8-month-olds do well

When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

Testing ability to distinguish
Salish & Hindi contrasts

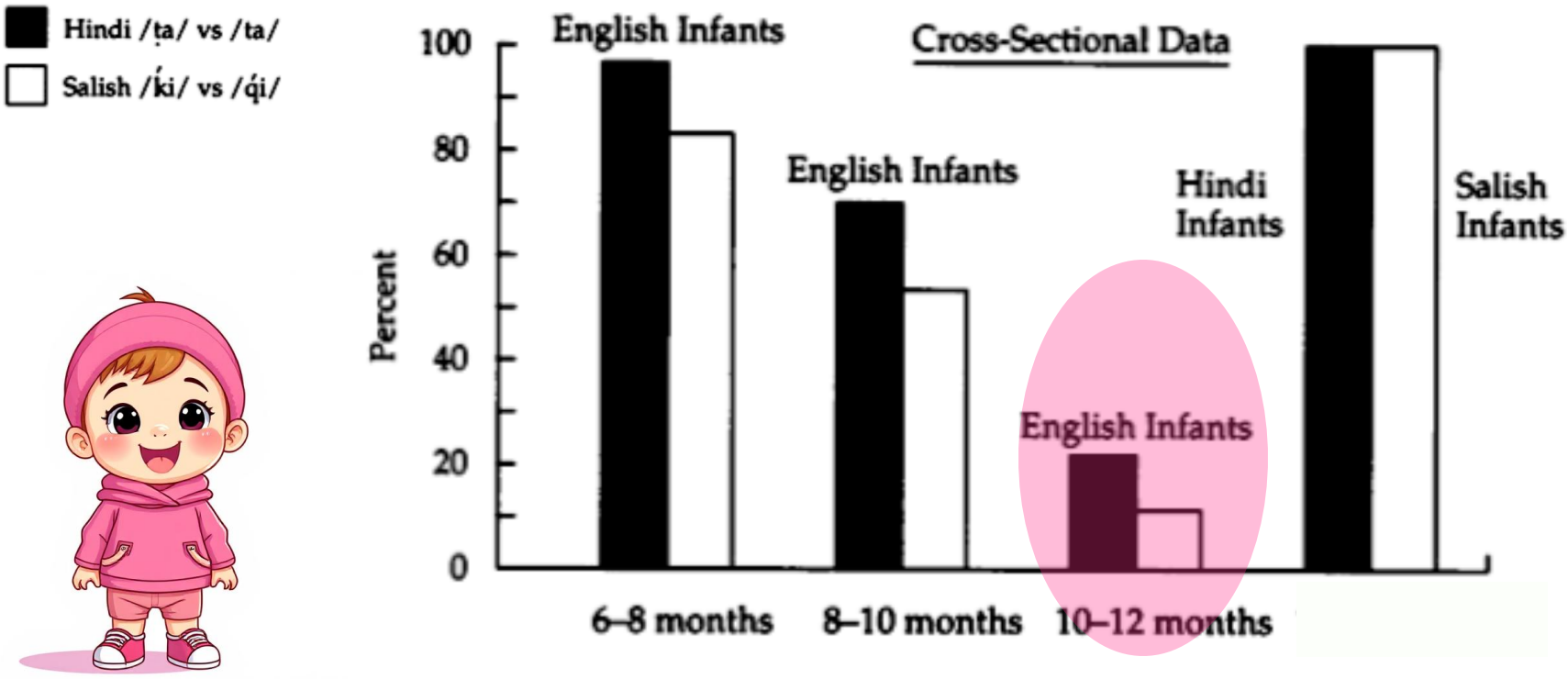


English 8- to 10-month-olds do less well

When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

Testing ability to distinguish
Salish & Hindi contrasts

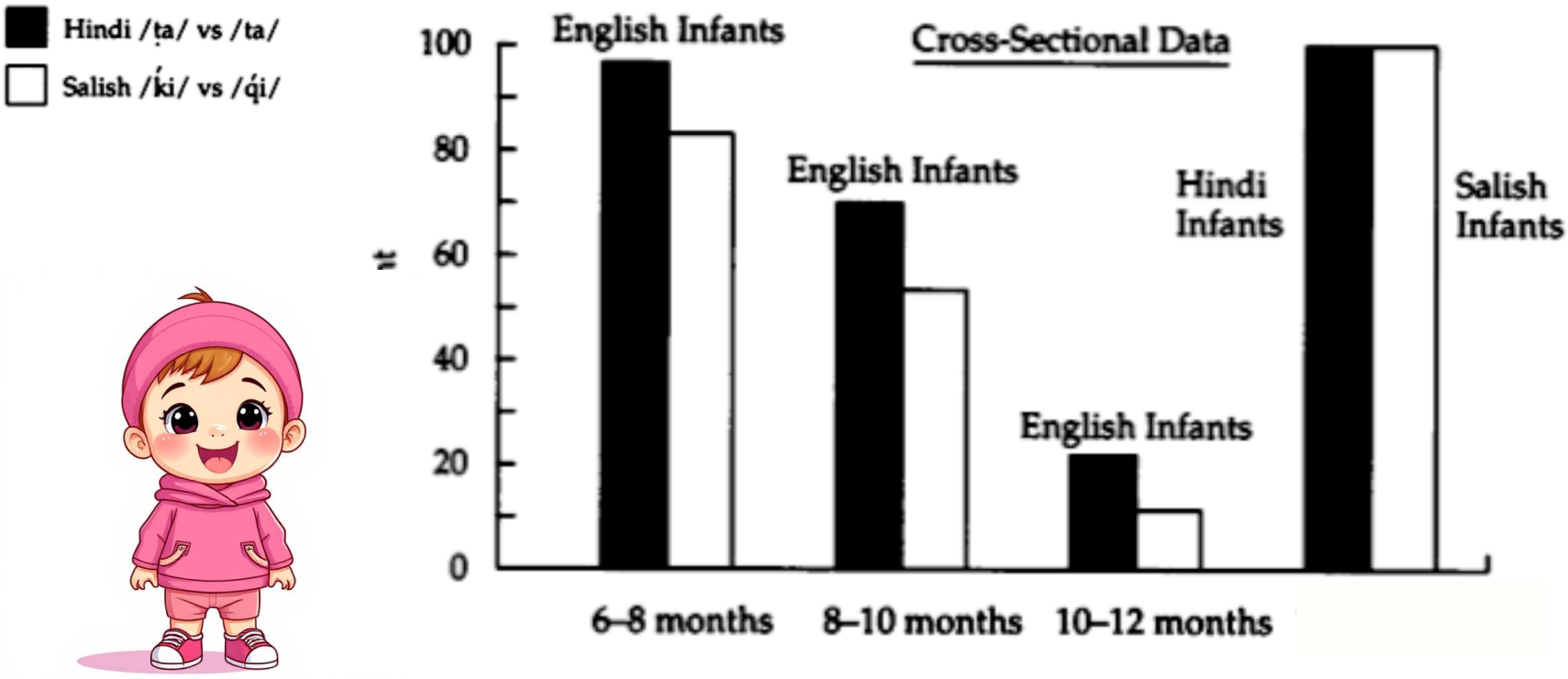


English 10 to 12-month-olds do very poorly

When change happens

But when after 6-8 months is the ability to lost? Werker & Tees (1984)

Testing ability to distinguish
Salish & Hindi contrasts



Implication: The ability to distinguish non-native contrasts is lost by 10-12 months. Change seems to be happening between 8-10 months.

When change happens

But when after 6-8 months is the ability to lost?

Werker & Tees (1984)

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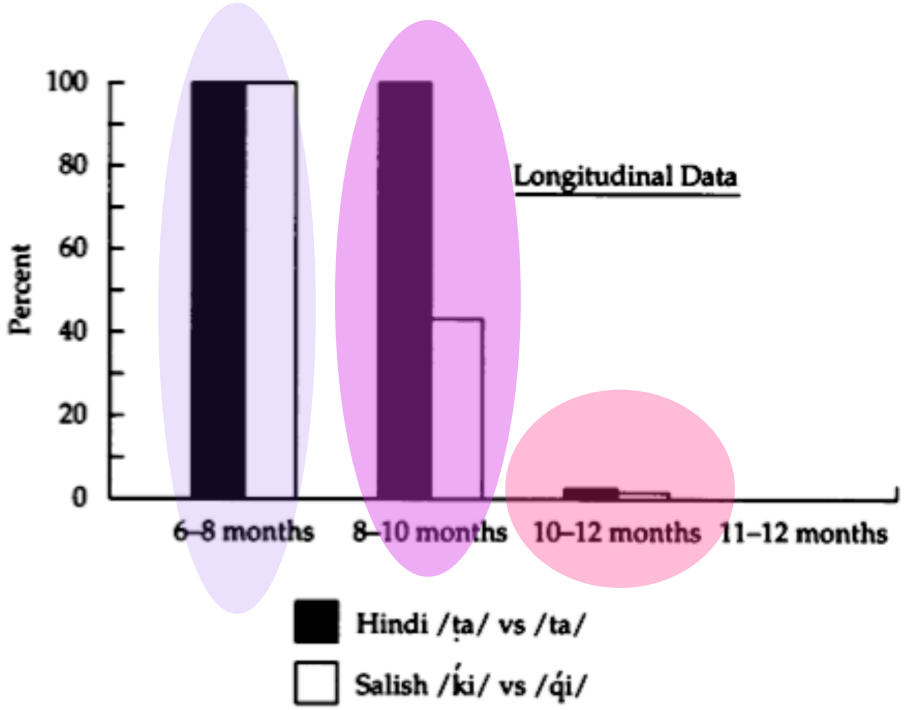
Salish & Hindi contrasts

Doing a longitudinal study with English infants (where the same infants are tested over time), change seems to happen somewhere around 10-12 months, depending on the sound contrast.



Yoshida et al. 2010, Singh, Cheng, & Yeung 2022: Infants have some malleability still at 10 months, but it's less than at 6 or 8 months. There are differences depending on the particular sound contrast.

When change happens

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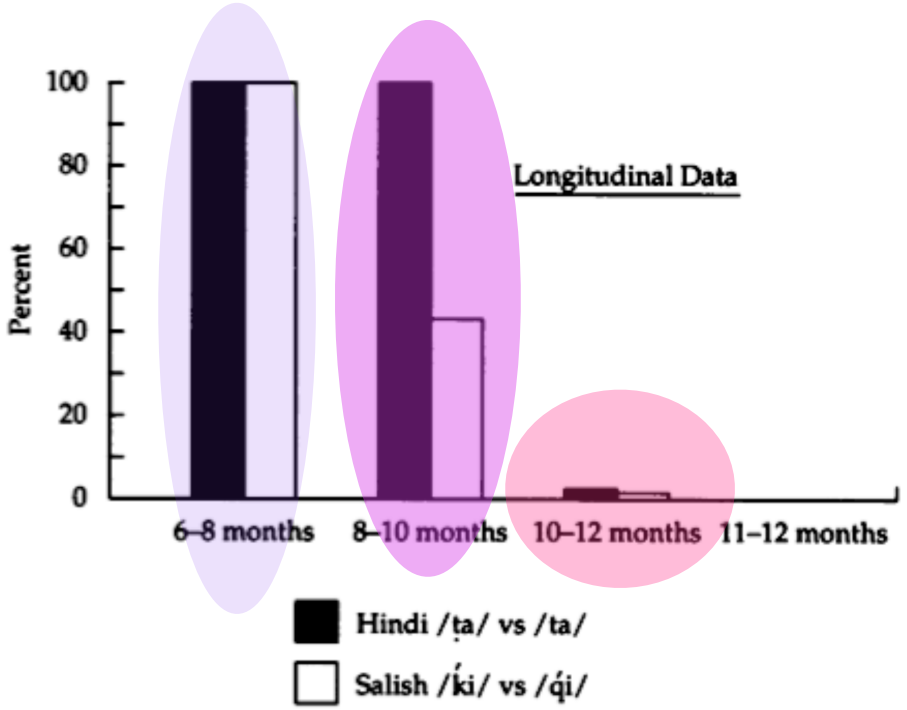

Singh, Cheng, & Yeung 2022, on variation: The change in (in)sensitivity to non-native contrasts doesn't depend on socio-economic status. However increased sensitivity to native contrasts does depend on socio-economic status of the mother.

When change happens

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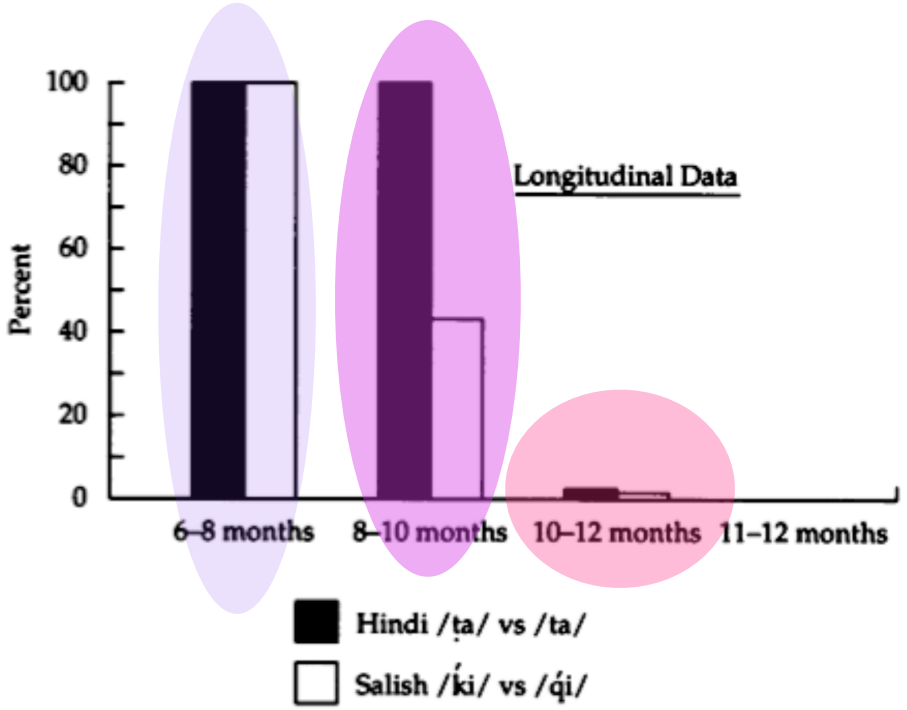


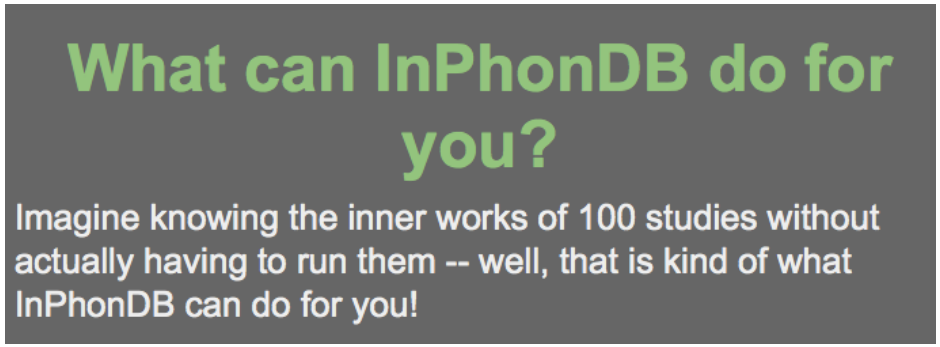
Quam, Clough, Knight, & Gerken 2020, on acoustic variation: Natural acoustic variation (from different people speaking — known as talker variability) doesn't seem to negatively impact this trajectory.

When change happens

[Extra]

For more examples of which sounds infants learn when and how to run studies that test this, check out the Infant Phonemic Discrimination DataBase.

https://sites.google.com/site/inphondb/



Recap: Speech sound development

Infant hearing is fine-tuned for speech perception even before babies are born.

One key feature of speech perception is categorical perception, where acoustically-distinct sounds are perceived as being the same.

Children need to learn which sound categories their language uses, which means tuning into contrasts that are used in their native language and ignoring contrasts that aren't used. This starts happening pretty early.

Questions?

You should be able to do up through question 10 on HW3, and up through question 12 on the phonological review questions.