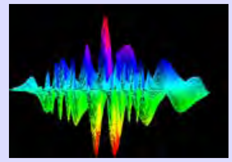
Psych 215L: Language Acquisition

Lecture 3

Speech Perception



Learning Sounds

Sounds of Language (Speech Perception)

Learner's job: Identify phonemes (contrastive sounds that signal a change in meaning)

big vs. pig

Phonemes are language-specific - r/l is a phonemic contrast in English but not in Japanese

Lisa = Risa for some of my Japanese friends

Kids of the world require knowledge of phonemes before they can figure out what different words are - and when different meanings are signaled by different words

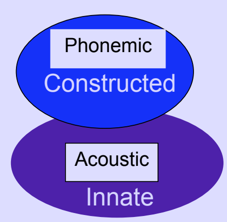
About Speech Perception

Important: Not all languages use the same contrastive sounds.

Languages draw from a common set of sounds (which can be represented by the International Phonetic Alphabet (IPA)), but only use a subset of that common set.

Child's task: Figure out what sounds their native language uses contrastively.

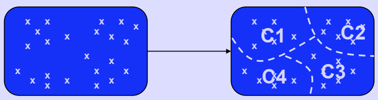
meaningful sounds in the language: "contrastive sounds" or phonemic contrasts



Speech Perception: Computational Problem

Divide sounds into contrastive categories (phonemes)

Here, 23 acoustically-different sounds are clustered into 4 contrastive categories. Sounds within categories are perceived as being identical to each other.



Speech Perception: Computational Problem

Real world data are actually much harder than this…
(from Swingley 2009)

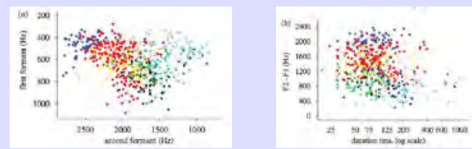
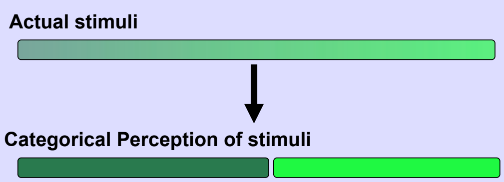


Figure 2. (*a*) First and second formants in about 700 vowels of one mother's speech to her infant. Each colour/shape combination indicates a different vowel. (*b*) Second formant minus first formant plotted against raw duration, for vowels of one mother's speech to her infant. Each colour/shape combination indicates a different vowel.

Categorical Perception

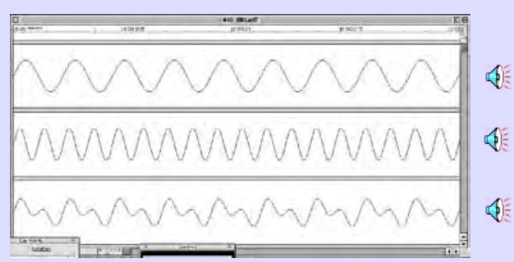
Categorical perception occurs when a range of stimuli that differ continuously are perceived as belonging to only a few categories with no degrees of difference within a given category.



Acoustic-Level Information

Includes: timing and frequency

Tones: frequency (close-up)



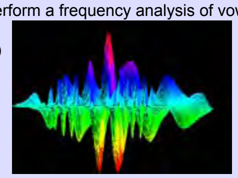
Acoustic-Level Information

Language sounds

Vowels combine acoustic energy at a number of different frequencies

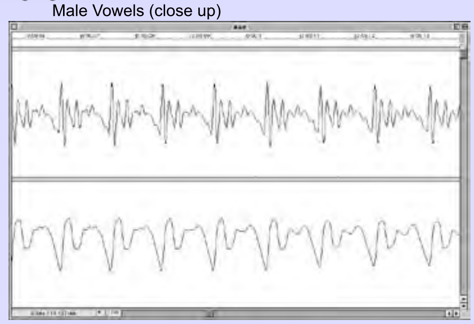
Different vowels ([a] “ah”, [i] “ee”, [u] “oo” etc.) contain acoustic energy at different frequencies

Listeners must perform a frequency analysis of vowels in order to identify them
(*Fourier Analysis*)



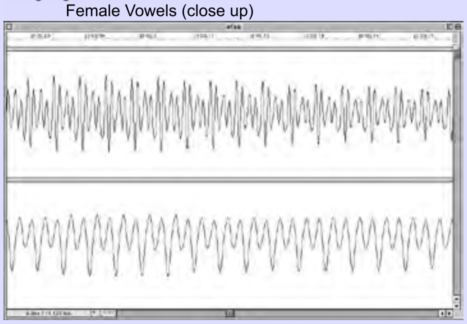
Acoustic-Level Information

Language sounds
Male Vowels (close up)



Acoustic-Level Information

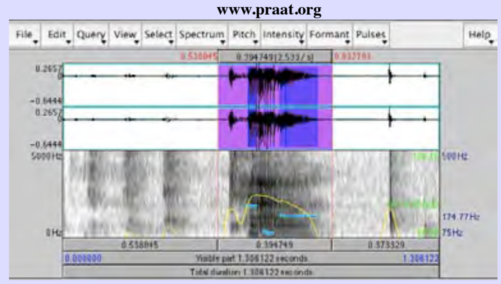
Language sounds
Female Vowels (close up)



Synthesized Speech

Allows for precise control of sounds

Valuable tool for investigating perception: **Praat**
www.praat.org



Acoustic-Level Information

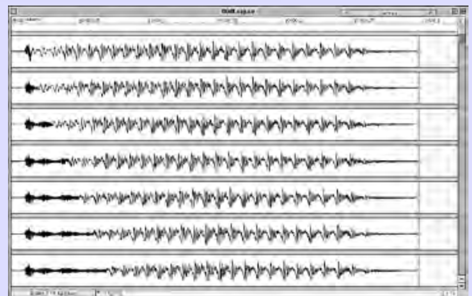
Language sounds

Timing: Voicing

Acoustic-Level Information

Language sounds

Timing: Voice Onset Time (VOT)



60 ms

English VOT production

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

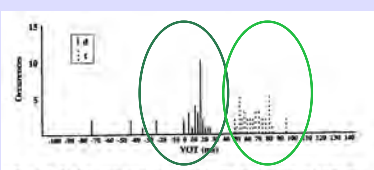
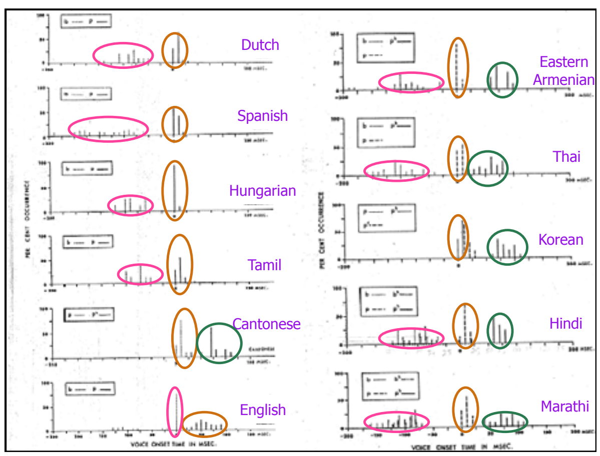


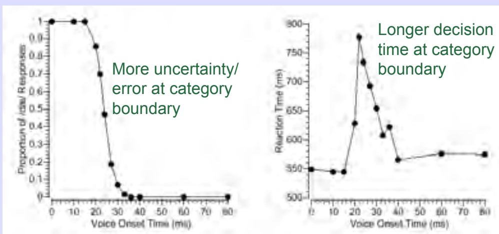
Figure 5–3. VOT productions of a single normal adult speaker of American English for words beginning with /d/ and /t/. (Figure adapted with permission from Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, (1980). Production Deficits in Aphasia: A Voice Onset-Time Analysis. *Brain and Language, 9,*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

Perception of stimuli: 2 categories



Perceiving VOT

‘Categorical Perception’: dæ vs. tæ



Decision between d/t **Time to make decision**

Identification task:“Is this sound dæ or tæ ?”

Discrimination Task
“Are these two sounds the same or different?”

Same/Different
0ms 60ms

Same/Different
0ms 10ms

Same/Different
40ms 40ms

Discrimination Task
“Are these two sounds the same or different?”

Same/Different
0ms 60ms

Same/Different
0ms 10ms

Why is this pair difficult?

(i) Acoustically similar?

(ii) Same Category?

Same/Different
40ms 40ms

Discrimination Task
“Are these two sounds the same or different?”

D 0ms 20ms D

D 20ms 40ms T

T 40ms 60ms T

Across-Category Discrimination is Easy

Within-Category Discrimination is Hard

Cross-language Differences

R L

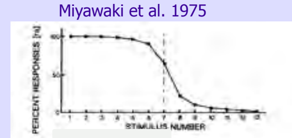
R L

Cross-Language Differences

Miyawaki et al. 1975

Identification task:

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



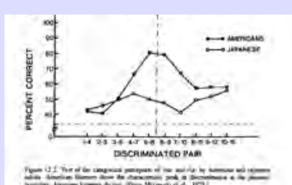
R ----------------------> L

Cross-Language Differences

Discrimination task:

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. 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



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

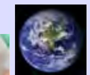
Salish
(Native North American language):
glotalized voiceless stops

Uvular – tongue is raised against the velum

Velar – tongue is raised behind the velum

(they are actually ejectives - ejective is produced by obstructing the airflow by raising the back of the tongue against or behind the velum)

Perceiving sound contrasts



Kids…

This ability to distinguish sound contrasts extends to phonemic contrasts that are non-native. (Japanese infants can discriminate contrasts used in English but not in Japanese, like r/l.) This goes for both vowels and consonants.

…vs. adults

Adults can't, especially without training - even if the different is quite acoustically salient.

So when is this ability lost?

And what changes from childhood to adulthood?

Speech Perception of Non-Native Sounds

Comparing perceptual ability

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

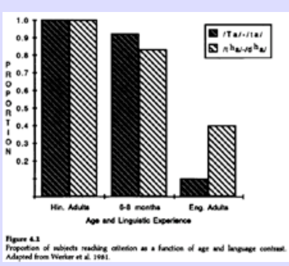


Figure 4.1
Proportion of subjects reaching criterion as a function of age and language contrast. Adapted from Werker et al. 1981.

Conditioned Head Turn Procedure

Werker (1995): Speech Perception

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

Werker & Tees (1984)

Key into "critical period" hypothesis for language (Lenneberg 1967) - when language can be learned natively

"To test for this critial period, children of 12 and 8 years were tested, with the expectation that the 8-year-olds but not the 12-year-olds would be able to discriminate nonnative contrasts. English-speaking children of both ages, however, performed like English-speaking adults…study was extended to 4-year old children, who actually performed most poorly of all on nonnative contrasts.…findings revealed that experience must begin to influence speech perception long before 4, certainly well before the critical period suggested by Lenneberg."

Speech Perception of Non-Native Sounds

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

Salish & Hindi contrasts

Change happens somewhere around 8-10 months, depending on the sound contrast.
See Yoshida et al. (2010) for evidence that infants have some malleability still at 10 months, but it's much less than at 6 or 8 months.

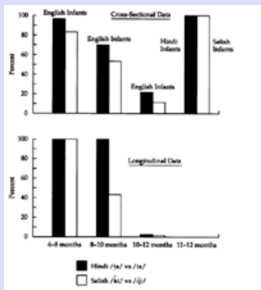


Figure 4.3
Proportion of infant subjects from three age groups and various language backgrounds reaching criterion on the Hindi and Salish contrasts. From Werker and Tees 1984a, 61.

Discovering contrastive sounds: What's the point of it again?

The idea is that once children discover the meaningful sounds in their language, they can begin to figure out what the words are.

Ex: An English child will know that "cat" and "caat" are the same word (and should have the same meaning).

As adults, we can look at a language and figure out what the contrastive sounds are by looking at what changes a word's meaning. But children can't do this - they figure out the contrastive sounds *before* they figure out words and word meanings.

More about contrastive sounds

There are a number of acoustically salient features for sounds. All it takes for sounds to be contrastive is for them to have "opposite" values for one feature.

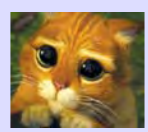
Example:
English sounds "k" and "g" differ only with respect to voicing. They are pretty much identical on all other features. Many contrastive sounds in English use the voicing feature as the relevant feature of contrast (p/b, t/d, s/z, etc.). However, there are other features that are used as well (air flow, manner of articulation, etc.).

Task for the child: Figure out which features are used contrastively by the language. Contrastive sounds for the language will usually vary with respect to one of those features.

Experimental Study: Dietrich, Swingley & Werker (2007)

Testing children's perception of contrastive sounds

Dutch and English contrastive features differ.



In English, the length of the vowel is not contrastive

"cat" = "caat"

In Dutch, the length of the vowel is contrastive

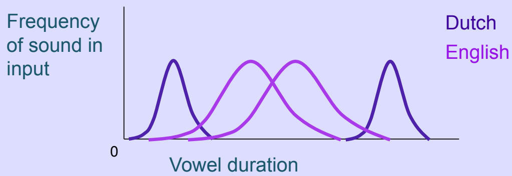
"cat" ≠ "caat"

(Japanese also uses this feature)

Does the data distribution show this?

Dutch and English vowel sounds in the native language environment also seem to differ

"…studies suggest that differences between the long and short vowels of Dutch are larger than any analogous differences for English."



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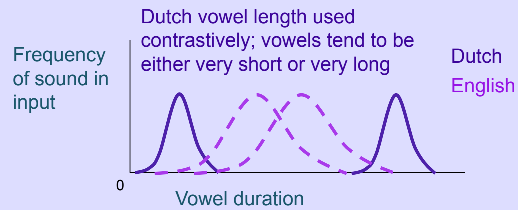

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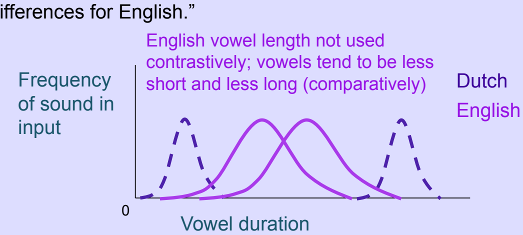

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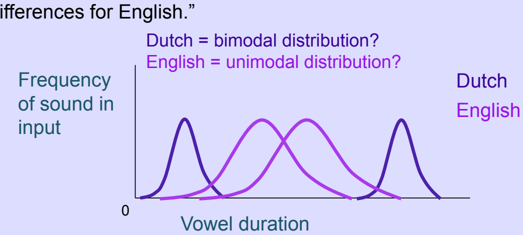

Does the data distribution show this?

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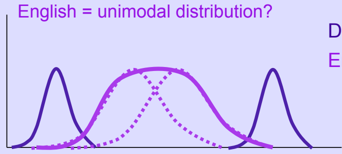
"…studies suggest that differences between the long and short vowels of Dutch are larger than any analogous differences for English."

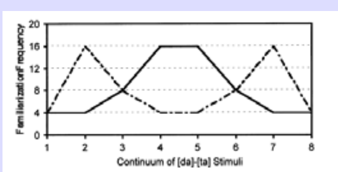
Dutch = bimodal distribution?
English = unimodal distribution?



Learning from real data distributions

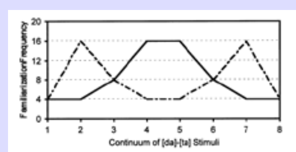
How do we know that children are sensitive to distributional information?

Maye, Werker, & Gerken (2002)



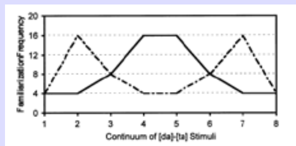
Created synthetic sounds ranging from [da] to [ta] that were non-native for the infants (because they were unaspirated).

Maye, Werker, & Gerken (2002)



- Familiarized 6 to 8-month-old infants to one of two sets
  - Bimodal Set: Sounds on the ends near [da] and [ta].
  - Unimodal Set: Sounds in the middle.
- Test preference for:
  - 3 6 3 6… (Alternating) vs. 3 3 3 3… (Non-alternating) stimuli

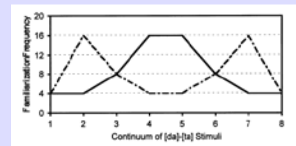
Maye, Werker, & Gerken (2002)



	3 6 3 6 … Alternating trials (s)		3 3 3 3 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)

Infants trained on the Bimodal data had a novelty preference for non-alternating trials. They learned to expect alteration, and were surprised by non-alteration.



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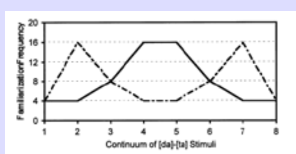
Maye, Werker, & Gerken (2002)

Infants trained on the Unimodal data did not prefer/ disprefer one over the other. The did not seem to learn any expectation.



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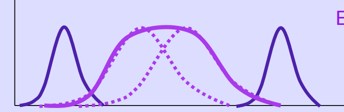
Back to Dietrich, Swingley, & Werker (2007)

Dutch and English vowel sounds in the native language environment also seem to differ

"…studies suggest that differences between the long and short vowels of Dutch are larger than any analogous differences for English."

Dutch = bimodal distribution?
English = unimodal distribution?



Back to Dietrich, Swingley, & Werker (2007)

Prediction if children are sensitive to this distribution

Dutch children interpret vowel duration as a meaningful contrast because the distribution is more bimodal

Implication: Change to vowel duration = new word

English children should not interpret vowel duration as a meaningful contrast because the distribution is more unimodal

Implication: Change to vowel duration = same word as before

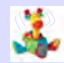
Dietrich, Swingley, & Werker (2007)

Tests with 18-month-old children who know some words (and so have figured out the meaningful sounds in their language)

“Switch” Procedure: measures looking time

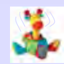
…this is a *tam*…look at the *tam*

Habituation



Test

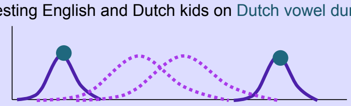
Same: look at the *tam!*



Switch: look at the *taam!*

Dietrich, Swingley, & Werker (2007)

Experiment 1: Testing English and Dutch kids on Dutch vowel durations



Dutch kids
5.04 sec 9.23 sec difference

English kids
6.66 sec 7.15 sec no difference

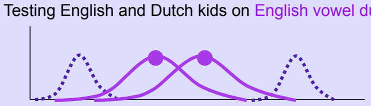
Test

Same: look at the *tam!*

Switch: look at the *taam!*

Dietrich, Swingley, & Werker (2007)

Experiment 2: Testing English and Dutch kids on English vowel durations



Dutch kids
5.92 sec 8.16 sec difference

English kids
7.34 sec 8.04 sec no difference

Test

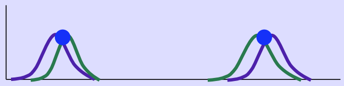
Same: look at the *tam!*

Switch: look at the *taam!*

Dietrich, Swingley, & Werker (2007)

Experiment 3: Testing English and Dutch kids on vowel quality contrast (a/e)

Frequency of sound in input



0 Vowel duration

(This is a control condition to make sure English kids can do the task when the sound is contrastive for them)

Dutch kids
4.08 sec 5.72 sec difference

English kids
6.31 sec 9.31 sec difference

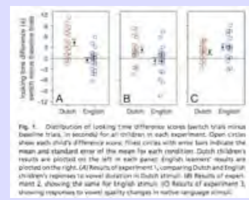
Test

Same: look at the *tam!*

Switch: look at the *tem!*

Dietrich, Swingley, & Werker (2007)

Just a note that experimental data with infants is messier than it sounds.

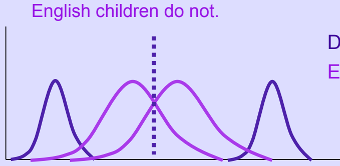


Dietrich, Swingley, & Werker (2007)

Implications of experiments 1, 2, and 3: Dutch children recognize vowel duration as contrastive for their language while English children do not. This can only be due to the data encountered by each set of children in their language.

Dutch children have a category boundary approximately here.
English children do not.

Frequency of sound in input



Dutch
English

0 Vowel duration

What drives children to learn the distinction?

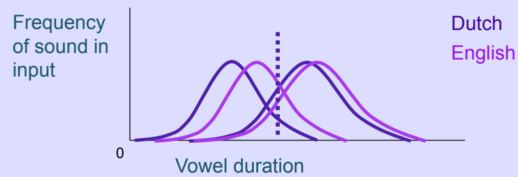
"One frequently raised hypothesis…is that it is driven by contrast in the vocabulary. Dutch children might learn that [a] and [a:] are different because the words [stat]…and [sta:t]…mean different things…however, children that young do not seem to know many word pairs that could clearly indicate a distinction between [a] and [a:]."

Dietrich, Swingley, & Werker (2007)

"The other current hypothesis is that children begin to induce phonological categories "bottom-up", based on their discovery of clusters of speech sounds in phonetic space…undoubtedly implicated in infants' early phonetic category learning, which begins before infants know enough words for vocabulary-based hypotheses to be feasible…"

Dietrich, Swingley, & Werker (2007)

"A necessary condition for such learning to be the driving force behind Dutch children's phonological interpretation in the present studies is that long and short vowels be more clearly separable in Dutch than in English…preliminary examination of this problem using corpora of Dutch child-directed speech indicated that the set of long and short instances formed largely overlapping distributions."



Implication: Dutch children need other cues to help them out

Swingley (2009)

One potential source of information: keep some contextual information for each vowel sound (what word it came from, if it comes from a frequent word).

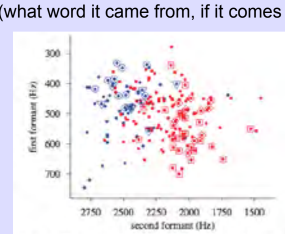
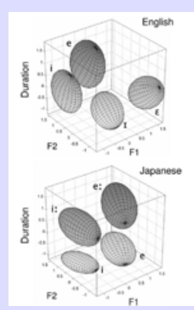


Figure 3. The vowels /i/ and /ɪ/ in first- and second formant space, as spoken by one mother to her infant. The /i/ instances are plotted as blue circles, /ɪ/ as red squares. Outlines around instances indicate tokens measured from the words *see* (open circles), *eat* (open triangles), *dillon* (open squares), and *this* (open diamonds).

Vallabha et al. (2007)

Also, not all distributions (and categorical features) may be so difficult to extract from acoustic information alone (like F1, F2, and duration).



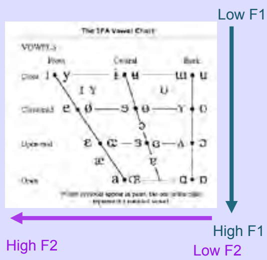
English vs. Japanese on 3 acoustic dimensions, from child-directed speech:

F1, F2, and Duration

English: F1 vs F2 creates 4 vowels

Japanese: F1 vs duration creates 4 vowels

Formants



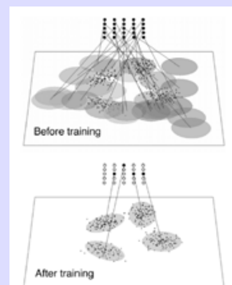
F1: depends on whether the sound is more open or closed. (Varies along y axis.) F1 increases as the vowel becomes more open and decreases as vowel closes.

F2: depends on whether the sound is made in the front or the back of the vocal cavity. (Varies along x axis). F2 increases the more forward the sound is.

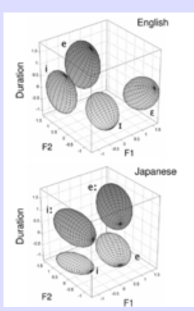
Idea: As long as speakers use the same values for these formants, they will produce the same vowel.

Vallabha et al. (2007)

A model trained on child-directed speech data can (mostly) find the four vowels approriate for each language.



An issue



An issue: There is considerable variation in formants (like F1 and F2) between speakers. How can they get these speaker-neutral values for these features?

Monahan & Idsardi (2010)

Human brains may be biased to extract this information by using certain normalization procedures.

"…We propose a novel formant ratio algorithm in which the first (F1) and second (F2) formants are compared against the third formant (F3). Results from two magnetoencephalographic experiments are presented that suggest auditory cortex is sensitive to formant ratios…we present statistical evidence that this algorithm eliminates speaker-dependent variation based on age and gender from vowel productions…"