Psych 150/ Ling 155: Psychology of Language

Lecture 6

Learning Aspects of the Sound System

Announcements

Be working on HW2, due on 5/5/15.

Be working on the review questions for acquisition.

Learning aspects of the sound system

Many aspects of the sound system are learned before children are a year old.

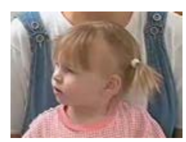
What this means practically: To assess what knowledge children learn when, researchers need to be very clever and use indirect methods.

Indirect experimental methods

Three procedures for investigating speech perception

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

- — High amplitude sucking (HAS) procedure (~0:25 — ~5:05)
- — Head turn preference procedure (~5:30 — ~8:20)
- — Preferential looking procedure (~9:20 — ~11:40)
- — Summary (11:40 to end)

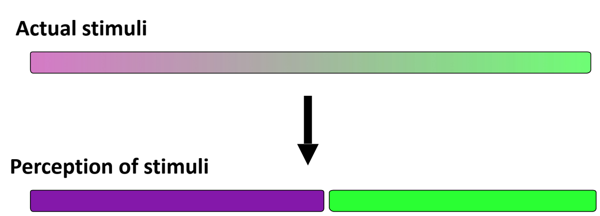

Sound categorical knowledge

"…when it comes to how we perceive speech, we aren't just responding to the actual physical sounds out in the world. The way in which we hear sounds has a lot to do with the structure our minds impose….can have dramatic effects in perceptually boosting some sound distinctions and minimizing others."

— Sedivy 2014, p.129

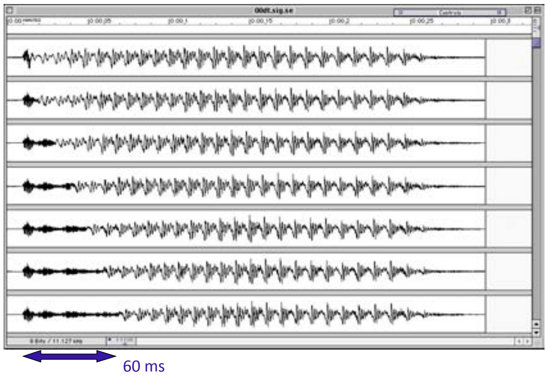
Categorical perception

One feature of human 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.



Categorical perception

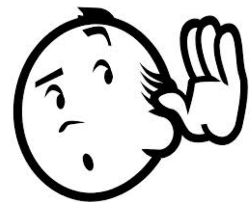
Adult categorical perception: Voice Onset Time (VOT)



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.)

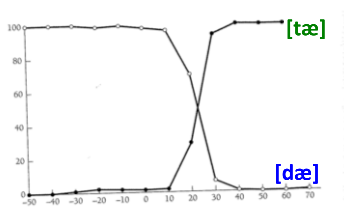
Ex: "Is this sound a /dæ/ or a /tæ/?"



Categorical perception

Adult categorical perception: Voice Onset Time (VOT)

% of responses as either /tæ/ or /dæ/

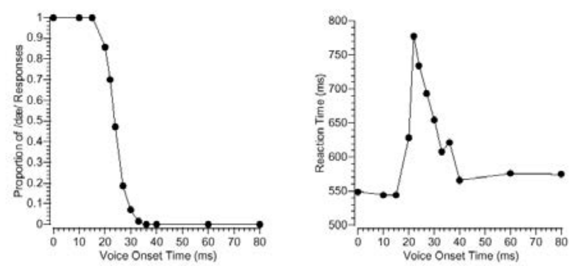


Voice onset time in msec

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

Categorical perception

Adult categorical perception: Voice Onset Time (VOT)



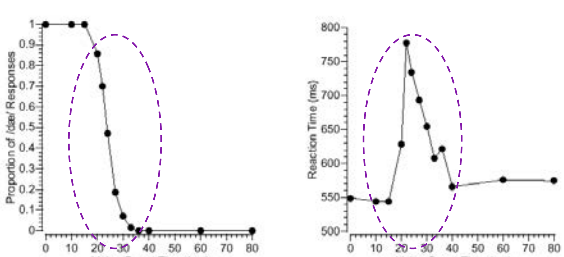
Decision between dæ/tæ

Time to make decision

Categorical perception

Adult categorical perception: Voice Onset Time (VOT)

Uncertainty at category boundary



Decision between dæ/tæ

Time to make decision

Categorical perception

Other places where we don't seem to have categorical perception: pitch, intensity

http://sites.sinauer.com/languageinmind/wa04.07.html

Audio 1: Voice onset time (VOT)

The synthesized sounds in this clip illustrate VOT values at 0, 10, 20, 30, and 40.

Audio 2: Pitch

Each of the five sounds is a semitone lower in pitch than the sound immediately following it.

Audio 3: Intensity

The five sounds are separated by increments of 3 decibels.

Categorical perception

Adult categorical perception: Voice Onset Time (VOT)

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

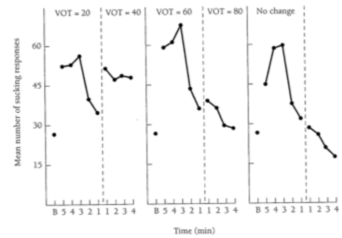
D	0ms	20ms	D
D	20ms	40ms	T
T	40ms	60ms	T

Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique

across category | within category | control (baseline)

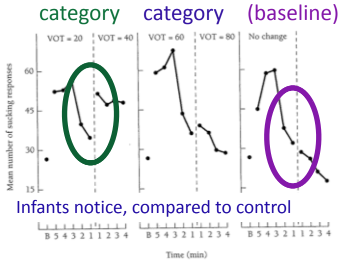


Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique

across category | within category | control (baseline)

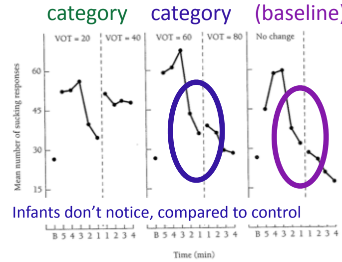


Categorical perception

Infant categorical perception: Voice Onset Time (VOT)

Eimas et al. 1971: HAS technique

across category | within category | control (baseline)



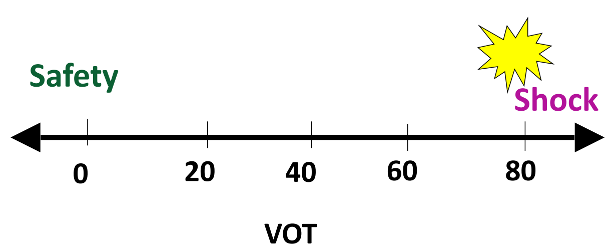
Categorical perception

Categorical perception: a special human linguistic 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). Notably, chinchillas aren't known for their linguistic skills.

Avoidance conditioning procedure

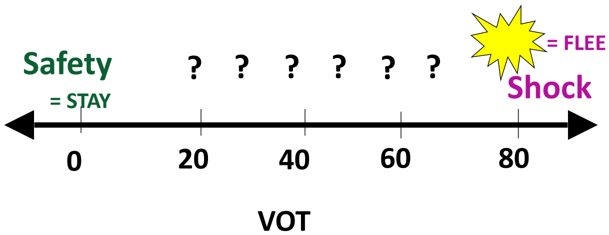
- Speech sound at one end of the continuum paired with shock
- Other end paired with safety



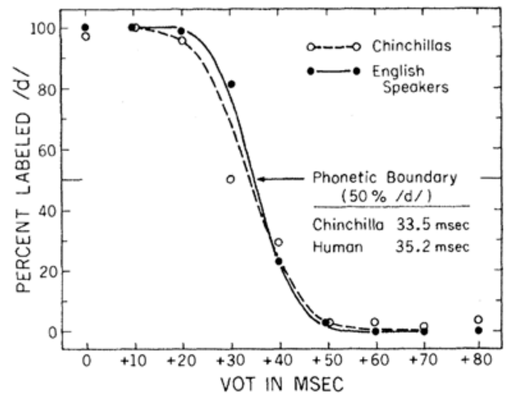
Avoidance conditioning procedure

Animals learn to "avoid" shock.

What will they do for between cases?



Kuhl & Miller 1978



Categorical perception

Categorical perception: a special linguistic ability?

Also, it turns out that many non-speech sounds are perceived categorically by infants as well — not just by humans, but by crickets and frogs too.

"So it looks as if the process of amplifying some sound distinctions while minimizing others is a very general property of the auditory system across species." — Sedivy 2014, p.132

Speech and non-speech sounds

VOT: the measure of time between the release of the articulators and the vibration of the vocal folds.

A more abstract way of looking at VOT: perceiving the relative timing of two distinct events.

Experimental method testing human ability to perceive relative timing between two sound events: the ABX discrimination task (Pisoni 1977).

Pisoni 1977: ABX discrimination task

Stimuli basis: Two distinct tones, which varied in the number of milliseconds that elapsed between the onset of the two tones ("Tone Onset Time" = TOT).

Ex: Tone 1 begins, and Tone 2 begins 20ms later. (TOT = 20ms)

Example stimuli: 20 vs. 30ms TOT

A: Two tones separated by 20ms (20ms TOT)

B: Two tones separated by 30ms (30ms TOT)

X = Two tones separated by 30ms

B!

Decision task: Is X like A or like B?

Pisoni 1977: ABX discrimination task

Stimuli basis: Two distinct tones, which varied in the number of milliseconds that elapsed between the onset of the two tones ("Tone Onset Time" = TOT).

Ex: Tone 1 begins, and Tone 2 begins 20ms later. (TOT = 20ms)

Example stimuli: 20 vs. 30ms TOT

A: Two tones separated by 20ms (20ms TOT)

B: Two tones separated by 30ms (30ms TOT)

X = Two tones separated by 20ms

A!

Decision task: Is X like A or like B?

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Example stimuli: 20 vs. 30ms TOT

A: Two tones separated by 20ms (20ms TOT)

B: Two tones separated by 30ms (30ms TOT)

X = Two tones separated by 20ms

Intuition behind the task: If subjects have categorical perception for certain time windows, they may perceive A and B as identical, even though these stimuli are acoustically distinct. This will make the decision about X difficult, and both accuracy and reaction time should suffer.

Pisoni 1977: ABX discrimination task

Core question: Is there a certain time window that humans are particularly sensitive to, even for non-speech sounds?

Pisoni (1977) found that people are especially good at distinguishing between stimuli right around a TOT of 20ms. However, distinguishing between a TOT of 40 and 50ms was very difficult, as was 0 vs. 10ms.

Easy

Example stimuli: 20 vs. 30ms TOT

A: Two tones separated by 20ms (20ms TOT)

B: Two tones separated by 30ms (30ms TOT)

X = Two tones separated by 20ms

Hard

Example stimuli: 40 vs. 50ms TOT, 0 vs. 10ms TOT

A: Two tones separated by 40ms (40ms TOT)

B: Two tones separated by 50ms (50ms TOT)

X = Two tones separated by 40ms

Pisoni 1977: ABX discrimination task

Core question: Is there a certain time window that humans are particularly sensitive to, even for non-speech sounds?

Implications:

(1) Yes. 20ms is when the auditory system is most easily able to detect that two events occurred at different times.

(2) The human speech system can be opportunistic, taking advantage of the natural perceptual biases of the human auditory system.

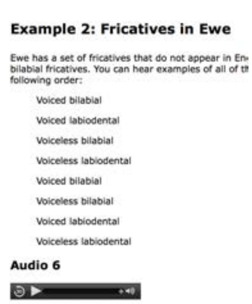
Sound distinctions

"Still, not all languages take advantage of the natural ways to carve up phonemic categories that the auditory system so conveniently offers up…there must be enough flexibility in the [babies'] perceptual systems to adapt to categories as defined by their particular language." — Sedivy 2014, p.134

Distinctive sounds for some adults

http://sites.sinauer.com/languageinmind/wa04.06.html

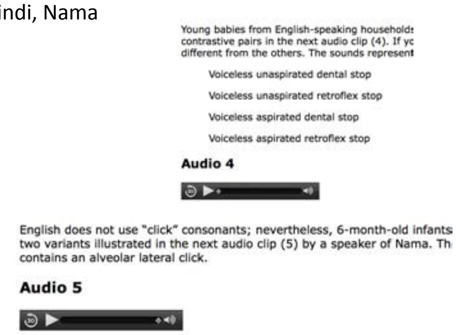
Irish, Ewe



Distinctive sounds for all infants

http://sites.sinauer.com/languageinmind/wa04.08.html

Hindi, Nama



Learning language-specific sound distinctions

How do babies learn how their language carves up the auditory space to make phonemic categories?

White et al. (2008): Perhaps children pay attention to how sounds are used.

One idea: Sounds used in complementary distribution may be allophones of the same phoneme, while sounds used in the same environments may be distinct phonemes in the language.

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
na bogu	rot pogu	na zobi	rot zobi	na sobi	rot sobi
na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

How many disyllabic words are there, based on this data?

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

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na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
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na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

What words does na appear in front of?

Environment for na: __b, __d, __z, __v, __s, __f

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na: __b, __d, __z, __v, __s, __f

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
na bogu	rot pogu	na zobi	rot zobi	na sobi	rot sobi
na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

What words does rot appear in front of?

Environment for rot: __p, __t, __z, __v, __s, __f

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na: __b, __d, __z, __v, __s, __f

rot: __p, __t, __z, __v, __s, __f

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
na bogu	rot pogu	na zobi	rot zobi	na sobi	rot sobi
na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

When do both words seem to be used (same environment)?

In front of z, v, s, f.

These are probably distinct phonemes.

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

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rot: __p, __t, __z, __v, __s, __f

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
na bogu	rot pogu	na zobi	rot zobi	na sobi	rot sobi
na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

When does only one word seem to be used (complementary distribution)?

na: __b, __d

rot: __p, __t

Generalization: Stops are not phonemic for [voice].
If na, use voiced stop.
If rot, use voiceless stop.

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na: __b, __d, __z, __v, __s, __f

rot: __p, __t, __z, __v, __s, __f

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
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na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

Given this, how many distinct disyllabic words are there?

12:

[bp]evi, [bp]ogu, [dt]ula, [dt]izu,

zuma, suma, zobi, sobi, veda, feda, vadu, fadu

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

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na: __b, __d, __z, __v, __s, __f

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na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
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na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

If I start a sequence with na, which sounds *can only* follow na?

Voiced stops: b, d, g

If I start a sequence with rot, which sounds *can only* follow rot?

Voiceless stops: p, t, k

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na: __b, __d, __z, __v, __s, __f

rot: __p, __t, __z, __v, __s, __f

na bevi	rot pevi	na zuma	rot zuma	na suma	rot suma
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na dula	rot tula	na veda	rot veda	na feda	rot feda
na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

Using the head-turn preference procedure, White et al. (2008) discovered that 8.5-month-olds formed exactly this expectation. They were sensitive to the complementary distribution.

Learning language-specific sound distinctions

White et al. (2008): Artificial language stimuli that were sequences of two words.

First word: na, rot

Second word: disyllabic CV

na: __b, __d, __z, __v, __s, __f

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na dizu	rot tizu	na vadu	rot vadu	na fadu	rot fadu

Using the head-turn preference procedure, White et al. (2008) discovered that 12-month-olds used this complementary distribution information to figure out which words were variants of the same word (like bevi and pevi) and which words were distinct (like zuma and suma).

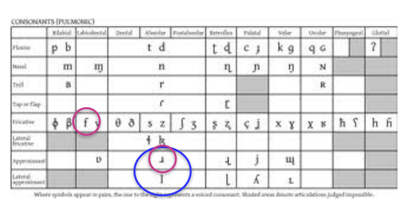
Naturalness

"Once you start looking at sound regularities across many different languages, a number of constraints and typical patterns start to emerge. For example, think of the generalization that determines whether voiceless sounds in English will be aspirated or unaspirated. Notice that it applies to *all* of the voiceless sounds of English, not just one or two of them."—Sedivy 2014, p.142

Generalization: Stops are not phonemic for [voice].
If na, use voiced stop.
If rot, use voiceless stop.

Naturalness

"It's also true that allophones of a single phoneme tend to have a lot in common phonetically—so, think of [p] and [p^h], but also of [r] and [l] which are allophones in Japanese and Korean. This means that it would be strange for two completely different sounds—say, [r] and [f]—to be in complementary distribution with each other…"—Sedivy 2014, p.142



Naturalness

"After surveying the world's languages, then, we can divide up hypothetical sound patterns into two groups: those that seem like natural, garden-variety generalizations, and those that are highly unnatural and involve patterns that are really unlikely to be found across languages."—Sedivy 2014, p.142

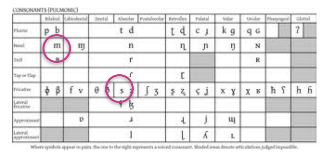
Naturalness

An example unnatural pattern:

Word-final /m/ and /s/ depend on whether there's a word-initial /k/ or /o/.

What makes this unnatural?

(1) /m/ and /s/ don't form a natural class of any kind.



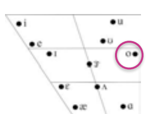
Naturalness

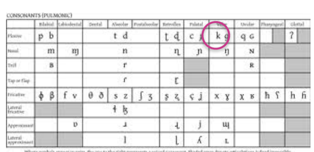
An example unnatural pattern:

Word-final /m/ and /s/ depend on whether there's a word-initial /k/ or /o/.

What makes this unnatural?

(2) /k/ and /o/ also don't form a natural class of any kind - they aren't even both vowels or both consonants.





Naturalness

An example unnatural pattern:

Word-final /m/ and /s/ depend on whether there's a word-initial /k/ or /o/.

Conclusion: This kind of unnatural pattern should be rare in the world's languages.

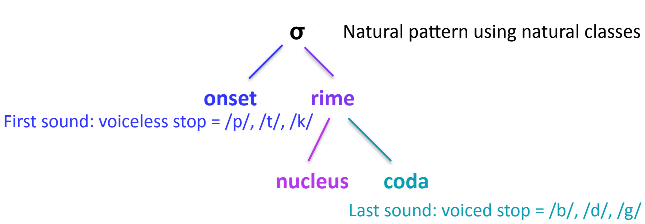
Question: Do babies have a bias towards more natural patterns that do appear?

k...........m

o...........s

Naturalness preferences

Saffran & Thiessen (2003):
Testing 9-month-old preferences for syllable patterns



Naturalness preferences

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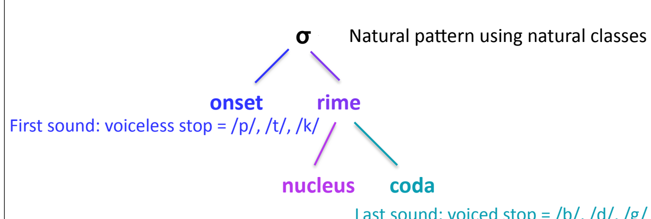
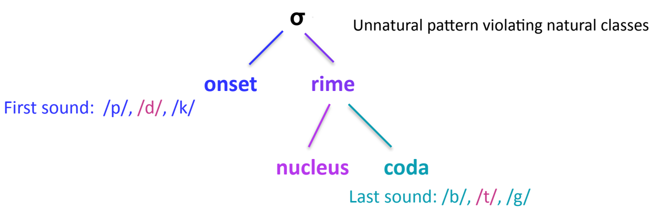


9-month-olds learned this pattern after hearing only 30 words, each repeated twice. (*pad, toog, keeb, …*)

Naturalness preferences

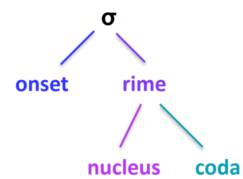
Saffran & Thiessen (2003):
Testing 9-month-old preferences for syllable patterns



9-month-olds failed to learn this pattern after hearing 30 words, each repeated twice. (*pat, doog, keeb, …*)

Naturalness preferences

Saffran & Thiessen (2003):
Testing 9-month-old preferences for syllable patterns



Implication: By 9 months, babies already have a preference to discover more natural sound patterns, where the sounds in complementary distribution fall into natural classes.

Recap

Children have to learn which sounds are distinctive in their language (phonemes).

Humans have categorical perception when it comes to speech sounds. This may build on natural perceptual abilities of the human auditory system in some cases, such as voice onset time.

Complementary distribution can be used as a cue for whether two sounds are allophones or distinct phonemes. Babies are sensitive to this cue and can actively use it. They also prefer allophones that form natural classes very early on.

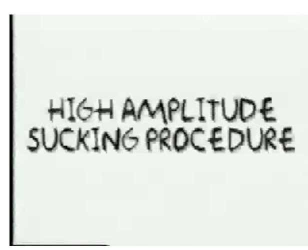
You should be able to do up through 27 on the learning review questions and up through 4 on HW2.

Extra Material

Studying infant speech perception

Researchers use indirect measurement techniques.

High Amplitude Sucking (HAS)



video ~4 minutes long

Studying infant speech perception

Researchers use indirect measurement techniques.

High Amplitude Sucking (HAS)

Infants are awake and in a quietly alert state. They are placed in a comfortable reclined chair and offered a sterilized pacifier that is connected to a pressure transducer and a computer via a piece of rubber tubing. Once the infant has begun sucking, the computer measures the infant's average sucking amplitude (strength of the sucks).

Studying infant speech perception

Researchers use indirect measurement techniques.

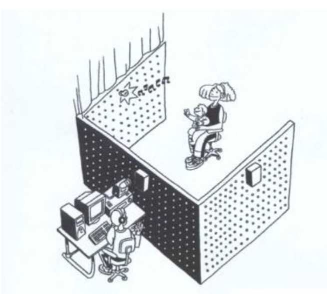
High Amplitude Sucking (HAS)

A sound is presented to the infant every time a strong or "high amplitude" suck occurs. Infants quickly learn that their sucking controls the sounds, and they will suck more strongly and more often to hear sounds they like the most. The sucking rate can also be measured to see if an infant notices when new sounds are played.

Studying infant speech perception

Researchers use indirect measurement techniques.

Head-Turn Preference Procedure

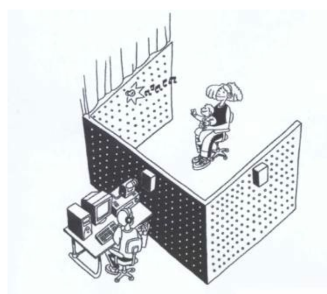


Infant sits on caretaker's lap. The wall in front of the infant has a green light mounted in the center of it. The walls on the sides of the infant have red lights mounted in the center of them, and there are speakers hidden behind the red lights.

Studying infant speech perception

Researchers use indirect measurement techniques.

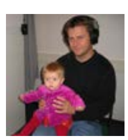
Head-Turn Preference Procedure



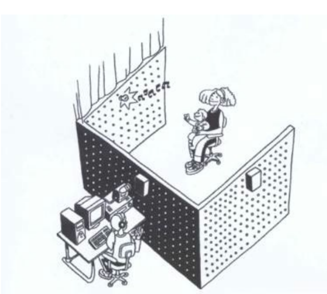
Sounds are played from the two speakers mounted at eye-level to the left and right of the infant. The sounds start when the infant looks towards the blinking side light, and end when the infant looks away for more than two seconds.

Studying infant speech perception

Researchers use indirect measurement techniques.



Head-Turn Preference Procedure



Thus, the infant essentially controls how long s/he hears the sounds. Differential preference for one type of sound over the other is used as evidence that infants can detect a difference between the types of sounds.

Studying infant speech perception

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Head-Turn Technique

http://www.youtube.com/watch?v=dAU5CAl1U6M

Especially 1:54-4:02

Studying infant speech perception

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Head-Turn Technique

Babies tend to be interested in moving toys. Using the presentation of a moving toy as a reward, babies are trained to turn their heads when they hear a change in the sound being presented.

Studying infant speech perception

Researchers use indirect measurement techniques.

Head-Turn Technique

A sound is played over and over, and then the sound is changed followed immediately by the presentation of the moving toy. After several trials, babies turn their heads when the sounds change even before the moving toy is activated.