A Puzzle

• Korean speakers use the sounds [r] and [l] e.g. Korea Seoul
• Korean babies hear the difference between [ra] and [la] … they don’t know Korean yet
• Korean adults know Korean … but they have difficulty hearing the [ra] vs. [la] contrast

Speech Perception

A speaker of a language is a prisoner of its ‘alphabet’ of sounds

Discrimination

A More Systematic Test

Within-Category Discrimination is Hard

Cross-language Differences

English vs. Japanese R-L
• American English pronunciation
  \[ m \ a k d \ a n a l d z \]
• Japanese pronunciation
  \[ m \ æ k u d o n a r u d o \]

Developmental Questions

• How does the native/non-native difference emerge?
• Does native-language discrimination improve with practice?

One Answer...

• Children learn the **feature contrasts** of their language
• Children learn gradually, adding features over the course of development

Roman Jakobson, 1896-1982

English VOT Perception

To Test Children
Not so easy!
High Amplitude Sucking

General Infant Abilities

• Infants’ show **Categorical Perception** of speech sounds - at 2 months and earlier
• Discriminate a wide range of speech contrasts
• Discriminate **Non-Native** speech contrasts e.g., Japanese babies discriminate r-l e.g., Canadian babies discriminate d-D
Universal Listeners

- Infants may be able to discriminate all speech contrasts from the languages of the world!

Varying Pronunciations

- Voiceless stops /p, t, k/
  - Voiced at start of syllable; unaspirated after [s]
  - 6 month olds easily distinguish bottom 2 rows; 1 year olds do not (adults aren’t great either)

How can they do this?

- Innate speech-processing capacity?
- General properties of auditory system?

What About Non-Humans?

- Chinchillas show categorical perception of voicing contrasts!

Connecting Hearing & Speaking

McGurk Effect


Evidence for connection

- Infants know connection between visual and auditory speech stimuli
- Mix and match [a] vs. [i]
Universal Listeners

• Infants may be able to discriminate all speech contrasts from the languages of the world!

When does Change Occur?

• About 10 months

Janet Werker
U. of British Columbia

Conditioned Headturn Procedure

When does Change Occur?

• Hindi and Salish contrasts tested on English kids

Janet Werker
U. of British Columbia

What has Werker found?

• Is this the beginning of Memory?
• Are the infants learning words?
• Or something else?

What does Development Involve?

• Change
• Loss

Patricia Kuhl
University of Washington

What does Development Involve?

• Growth

[from Phillips 2001]
What does Development Involve?

• Change - non-native categories *lost*
• Growth - non-native categories *hidden*

Varying Pronunciations

• Voiceless stops /p, t, k/
  - pit  tick
  - spit  stack
  - spit  stack
  - bit  dock

• Aspirated at start of syllable; unaspirated after [s]
• 6-month-olds easily distinguish bottom 2 rows; 1-year-olds do not (adults aren’t great either)

What does Development Involve?

• Evidence for *Growth*
  (i) Some discrimination retained when sounds presented close together (e.g. Hindi d-D contrast)
  (ii) Discrimination abilities better when people hear sounds as non-speech
  (iii) Adults do better than 1-year-olds on some sound contrasts
• All evidence comes from *consonants*

What yearlings can’t do

• Recognize minimal pairs while relating them to real words
  – “bear” versus “pair”
  – “Piglet” versus “Biglet”
• More Werker experiments

What does Development Involve?

• Evidence for *Change*
  (i) No evidence of preserved non-native category boundaries in vowel perception
    (non-native vowel *discrimination* is pretty good in any case)
• Best evidence for *change* comes from vowels and vowel-like categories

How do we learn native-language sound categories (by age 1)?

Theory 1: Sound Distributions
Theory 2: Minimal Pairs
Theory 3: Word Distributions
Word Learning

- Stager & Werker 1997
  ‘bih’ vs. ‘dih’ and ‘lit’ vs. ‘neem’

Why Yearlings Fail on Minimal Pairs

- They fail specifically when the task requires word-learning
- They do know the sounds
- But they fail to use the detail needed for minimal pairs to store words in memory
- What is going on?
  – Is this true for all words?
  – When do they learn to do this?
  – What triggers the ability to do this?

Swingley & Aslin, 2002

- 14-month olds did recognize mispronunciations of familiar words

| Table 1. Correctly pronounced (CP) target words and their mispronounced (MP) versions |
|---------------------------------|---------------------------------|---------------------------------|
| CP                                      | MP-close                       | MP-distant                      |
| apple (a/ppl)                     | apple (a/ppl)                  | opal (o/pal)                   |
| baby (be/bi)                      | baby (be/bi)                   | baby (be/bi)                   |
| ball (b/ul)                       | ball (b/ul)                    | ball (b/ul)                    |
| cat (ka/t)                        | cat (ka/t)                     | kite (ki/t)                    |
| dog (du/g)                        | dog (du/g)                     | mog (mo/g)                     |
| kitty (ki/ti)                     | kitty (ki/ti)                  | yaky (yi/kai)                  |

Note: International Phonetic Alphabet transcriptions are provided in parentheses. Bright trials were started on the first syllable.
Maybe not so bad after all...

- Children learn the feature contrasts of their language
- Children may learn gradually, adding features over the course of development
- Phonetic knowledge does not entail phonological knowledge

Roman Jakobson, 1896-1982

More…

- Word-learning is very hard for younger children, so detail is initially missed when they first learn words
- Many exposures are needed to learn detailed word forms at early stages of word-learning
- Success on the Werker/Stager task seems to be related to the vocabulary spurt, rapid growth in vocabulary after ~50 words

One-Year Olds Again

- One-year olds know the surface sound patterns of the language
- One-year olds do not yet know which sounds are used contrastively in the language...
  - ...and which sounds simply reflect variation that does not affect meaning
- One-year olds need to learn contrasts

We need another level!

Same or different?

<table>
<thead>
<tr>
<th>light</th>
<th>lied</th>
</tr>
</thead>
<tbody>
<tr>
<td>tight</td>
<td>tied</td>
</tr>
<tr>
<td>site</td>
<td>sighed</td>
</tr>
<tr>
<td>life</td>
<td>live</td>
</tr>
<tr>
<td>knife</td>
<td>knife(s)</td>
</tr>
<tr>
<td>lice</td>
<td>lies</td>
</tr>
<tr>
<td>dice</td>
<td>dies</td>
</tr>
</tbody>
</table>

Some people have this system:

<table>
<thead>
<tr>
<th>light</th>
<th>lajt</th>
<th>lied</th>
<th>lajd</th>
</tr>
</thead>
<tbody>
<tr>
<td>tight</td>
<td>tajt</td>
<td>tied</td>
<td>tajd</td>
</tr>
<tr>
<td>site</td>
<td>sajt</td>
<td>sighed</td>
<td>sajd</td>
</tr>
<tr>
<td>life</td>
<td>lajf</td>
<td>live</td>
<td>lajv</td>
</tr>
<tr>
<td>knife</td>
<td>najf</td>
<td>knife(s)</td>
<td>najvz</td>
</tr>
<tr>
<td>lice</td>
<td>lajs</td>
<td>lies</td>
<td>lajz</td>
</tr>
<tr>
<td>dice</td>
<td>dajs</td>
<td>dies</td>
<td>dajz</td>
</tr>
</tbody>
</table>
Some people have this one:

<table>
<thead>
<tr>
<th>light</th>
<th>lsjt</th>
<th>lied</th>
<th>lajd</th>
</tr>
</thead>
<tbody>
<tr>
<td>tight</td>
<td>lsjt</td>
<td>tied</td>
<td>lajd</td>
</tr>
<tr>
<td>site</td>
<td>sajt</td>
<td>sighed</td>
<td>sajd</td>
</tr>
<tr>
<td>life</td>
<td>lsjf</td>
<td>live</td>
<td>lajv</td>
</tr>
<tr>
<td>knife</td>
<td>nadjf</td>
<td>knife(s)</td>
<td>najvz</td>
</tr>
<tr>
<td>lice</td>
<td>lasjs</td>
<td>lies</td>
<td>lajz</td>
</tr>
<tr>
<td>dice</td>
<td>dajs</td>
<td>dies</td>
<td>dajz</td>
</tr>
</tbody>
</table>

What’s the pattern?

<table>
<thead>
<tr>
<th>voiceless alveolar stop</th>
<th>t</th>
<th>voiced alveolar stop</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>voiceless labiodental fricative</td>
<td>f</td>
<td>voiced labiodental fricative</td>
<td>v</td>
</tr>
<tr>
<td>voiceless alveopalatal fricative</td>
<td>s</td>
<td>voiced alveopalatal fricative</td>
<td>z</td>
</tr>
</tbody>
</table>

So these speakers have a rule ...

Before a voiceless consonant aj → āj

Isn’t it just two sets of words?

| lsjs  | lajz  | dajs  | dajz  | lajf  | lajz  | sajt  | sajd  | laj  | lajd |

Nope, it’s a rule ...

<table>
<thead>
<tr>
<th>stied</th>
</tr>
</thead>
<tbody>
<tr>
<td>stight</td>
</tr>
</tbody>
</table>

Nope, it’s a rule ...

<table>
<thead>
<tr>
<th>[stajd]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[stājt]</td>
</tr>
</tbody>
</table>
The sounds you "store" in your head

Terminology

/lajt/
/lajd/

"phonemes"

The sounds you actually produce

Terminology

/lajt/
[lajd]

Terminology

1 phoneme; more than 1 phone

/aj/ 

[ʌj]

We call the phones allophones of the phoneme

Or, more succinctly:

This phoneme

aj

So:

• In some dialects of English, the phoneme /aj/ has two allophones: [aj] and [ʌj].
• The allophone [ʌj] occurs whenever the phoneme precedes a voiceless sound

Or, more succinctly:

aj →
Or, more succinctly:

\[ aj \rightarrow \lambda j \]

this sound (allophone)

immediately before

\[ aj \rightarrow \lambda j / \_\_ \]

a voiceless sound

\[ aj \rightarrow \lambda j / \_\_ [-voice] \]

Another rule:

\[ t \rightarrow d /V\_\_V \]

Another rule:

- “sit” [sit]
- “sitter” [sid\textael]
- “heat” [hit]
- “heater” [hid\textael]
- “at” [\textael]
- “attic” [\textaeldk]

What about these?

- “attack”
- “atone”
- “determine”
- “detect”
Is there a pattern?

[sidar]  [aæk]
[hidør]  [əfon]
[ædik]  [difekt]

So we need a slight revision

\[ t \rightarrow d /\tilde{\text{V}} \quad \text{V} \]

1 phoneme

/t/
(sound stored in the brain)

1 phoneme 2 allophones

/t/  
[d]  [t]
(sound(s) actually produced)

What do you have in your head?

/t, f, p.../

/rules/  
/rules/
Points to note:

• Sequence becomes “easier to say”
  BUT
• This process is a specific rule of a particular dialect of English

In what sense a specific rule?

• doesn’t apply to all instances of “t” between vowels
• isn’t a part of the grammar of other dialects of English
• is only one way to make sequences of vowels and voiceless consonants easier to say

Moral:

The rules that we discover are often “natural” in that one can find an explanation for many of them in terms of ease of articulation, but they are not inevitable/innate: they are specific rules of particular dialects or languages, and had to be learned.

A way to think about phonemes

• You have a “mental dictionary” where you store the words you have learned.
• What information does it have to contain for each word?
  • At least:
  • the meaning of the word
  • the sound of the word

If you can predict something by a rule, you don’t have to remember it

Just remember:

• the rule
• the things that can’t be predicted

A way to think about phonemes

• How much detail do you have to remember about the sound of each word?
Allophonic differences ignored by hearers

Rules

\[ \text{[aj]} \]

\[ \text{[aj]} \]

Varying Pronunciations

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Languages can differ in what is predictable

Korean has [l] & [r]

- [rupi] “ruby”
- [kiri] “road”
- [saram] “person”
- [irumi] “name”
- [ratio] “radio”
- [mul] “water”
- [pal] “big”
- [soul] “Seoul”
- [ilkop] “seven”
- [ipalsa] “barber”

But [r] doesn’t show up everywhere...

[r] is always in front of a vowel

[r] is always in front of a vowel

And nor does [l]...

[l] is never in front of a vowel
So in Korean, [l] and [r] are “the same”

1 phoneme

(sound stored in the brain)

1 phoneme 2 allophones

sound(s) actually produced

While English works like this:

2 phonemes 2 phones

sound(s) actually produced

Even more schematically:

 Stored  | Produced
-------|--------
 English | /l/  →  [l]  /r/  →  [r]
 Korean  | /l/  →  [l]  /r/  →  [r]
Minimal Pairs

- In English, [r] and [l] can occur in the same position in a word:
  - rake
  - ramp
  - rim
  - ripper
- In English, [r] and [l] can be used to mark a meaning contrast.
- In English, /r/ and /l/ are two phonemes.
- Korean works differently:
  - [r] and [l] are two allophones of a single phoneme in Korean.
  - It’s impossible to create minimal pairs which contrast r/l in Korean.
  - [r] and [l] cannot be used contrastively in Korean.

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Word Learning

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