3 stages of phonological development
1. Prelinguistic vocal behaviors
2. Phonology of the first 50 words
3. Emergence of rules

Prelinguistic vocal behaviors
• Reflexive/vegetative sounds (birth-1 month)
• Cooing (2-3 months)
• Vocal play (4-6 months)
• Reduplicated babbling (7-9 months)
• Variegated babbling (10 months-1 year)
• Jargon (12-18 months)

Stage 1 (birth-1 month)
• reflexive sounds: crying, fussing
• vegetative sounds: burping, swallowing, spitting up

Stage 2 (2-3 months)
• “cooing” stage
• productions are acoustically similar to velars
• CV timing not yet adult-like

Stage 3 (4-6 months)
• “vocal play”
• experimentation with nonsegmental features: pitch, loudness, rhythm, vocal register
• experimentation with articulators: raspberries, tongue clicks, trills
• CV timing still not adult-like

Stage 4 (7-9 months)
• “reduplicated” babbling
• CV timing approximates that of adult speech
• limited phonetic repertoire
  • lax vowels [ɪ, ɛ, ʌ] predominate
  • stops, nasals, and glides most common consonants
  • alveolars replace velars as most frequent place of articulation; bilabials also increase
Stage 5 (10 months-1 year)

- "variegated" babbling
- variety of consonants and vowels can co-occur, e.g. [bæwidə]
- consonant repertoire increases substantially but stops, nasals, and glides are still most frequent
- adult-like intonation patterns occur

Jargon (12-18 months)

- longer syllabic strings
- more varied intonation patterns
- overlap with child’s true first words

Categorical perception

- voice onset time (VOT)
- lag in milliseconds

Techniques for studying speech perception

- high amplitude sucking

Categorical Perception

- Using “preferential sucking rate” measures, infants as young as 1 month of age appear able to discriminate [p] from [b] based on Voice Onset Time (VOT)
- Place and manner of articulation differences can be detected by age 3 months

• heart rate
  - works similarly to high amplitude sucking
  - not as effective
• visually reinforced speech discrimination toys

speaker with visual display
Discrimination of Non-native Sounds

- Up to approximately 6-8 months of age, infants can discriminate among sounds that they had not been exposed to, then the ability is lost.
- Suggests that discrimination ability is something we are born with.
- Language experience may cause us to ignore differences that are not functional.

Perceptual Constancy

- The acoustic characteristics of speech sounds produced by speakers of different ages and sexes vary widely.
- As listeners we are able to identify the sound regardless of who the speaker is.
- Categorization is possible by 6-8 months.

<table>
<thead>
<tr>
<th>papapa</th>
<th>baba</th>
<th>papa</th>
</tr>
</thead>
<tbody>
<tr>
<td>pipopi</td>
<td>bibi</td>
<td>pipi</td>
</tr>
</tbody>
</table>

Infants ignore vowel and speaker "noise" and respond to consonant change.

Auditory-visual mapping ("speechreading") in infants

- Infants detect mismatched auditory-visual stimuli.

[ɑ] [i]

Phonology of the first 50 words

- Preference for some sounds and avoidance of others:
  - Bilabial preference: bubble, bottle, baby
  - Avoidance of [u]: no juice, shoe, moo
  - Not evidenced in all children
  - Short-lived

Progressive idioms

- Their disappearance gives the appearance of regression
  - Down [daʊn] → [nʌn]
  - Stone [doʊn] → [nʌn]
  - Beans [biːz] → [miːz]

Early Segmental Development

- Some generalizations from several studies:
  - CV, VC & CVC syllable shapes most common.
  - Greater variety of sounds in initial position.
  - Voiced sounds more common in initial position (voiceless in final).
  - Up to 70% of consonants attempted are correctly produced (may be choosing words containing consonants they are able to produce).
Phonetic inventory of toddlers
Initial Position

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean Size</th>
<th>Phones in 50% of kids</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mos</td>
<td>3.4 (2-5)</td>
<td>b d h</td>
</tr>
<tr>
<td>18 mos</td>
<td>6.3 (2-10)</td>
<td>b d m n h w</td>
</tr>
<tr>
<td>21 mos</td>
<td>6.7 (2-13)</td>
<td>b t d m n h</td>
</tr>
<tr>
<td>24 mos</td>
<td>9.5 (4-16)</td>
<td>b t d k g m n h w f s</td>
</tr>
</tbody>
</table>

Phonetic inventory of toddlers
Final Position

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean Size</th>
<th>Phones in 50% of kids</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mos</td>
<td>0.6 (0-2)</td>
<td>(none)</td>
</tr>
<tr>
<td>18 mos</td>
<td>2.8 (0-6)</td>
<td>t</td>
</tr>
<tr>
<td>21 mos</td>
<td>3.6 (0-7)</td>
<td>t n</td>
</tr>
<tr>
<td>24 mos</td>
<td>5.7 (0-11)</td>
<td>p t k n r s</td>
</tr>
</tbody>
</table>

Linguistic Perception

- Requirements of the child - a speech stimulus must be
  - heard
  - registered
  - interpreted
- Distinction between sensory capacity and use of that capacity to distinguish among words

What counts as evidence of linguistic perception?

- a behavioral response (pointing, picking up object, etc.)
- an unambiguous response
- a response within the child’s repertoire

Perceptual Difficulties

- Confusion among fricatives and liquids may persist
- May be partly responsible for persistence of errors within these classes

Internal Representations

- These are the "blueprints" for phonological structures that reside in a child’s brain
- They cannot be observed directly but must be inferred from limited perceptual evidence as well as evidence from children’s immature productions
Internal Representations

- most methods of phonological analysis and intervention assume adult-like representations
- available evidence suggests
  - word shapes are represented earlier
  - immature representations may persist for clusters, fricatives, liquids
- a child with adult-like representations may still have production errors because of a lack of self-monitoring

Emergence of rules

- beyond the single-word period, we begin to see consistency and regularity in children’s renditions of adult words
- phonological process is a systematic sound change that affects classes of sounds or sound sequences

Adult vs. Child Speech

- Young typically-developing children produce segmental errors.
- Children articulate the segments at a slower rate than adults.
- Children’s speech may be more variable than adult speech.
- Children anticipate upcoming segments less than adults (less coarticulation).

Preschool Phonological Development

- Largest gains in phonological development occur between 1;6 and 5;0 for most children.
- Accompanied by many gains in other aspects of language development (especially semantics and syntax).

The Preschool Child

- At the appearance of two-word combinations (when the lexicon is about 50 words), the child still has limited inventories (both phonemes and syllable shapes).
- Still quite unintelligible; unfamiliar listeners typically understand < 50% of what they say.

Vowel Development

- Has not been examined very well.
  - Problems with vowel transcription.
  - Vowels rarely a problem clinically.
    - major exceptions = [ɔ] and [œ].
    - Can be a problem for children with obvious speech motor problems (e.g., cerebral palsy).
    - Data suggest that 70% of children have mastered all the vowels by about age 3;0.
Consonant Development

- Much more research done here.
- Consonants more of a clinical issue than vowels.
- Most studies are cross-sectional.
  - Look at several age groups at the same time.
  - Cohort problem: Did the oldest children previously perform like the youngest children do now and will the youngest children perform in the future like the oldest do now?

Consonant Development

- Biggest problems with comparing the studies:
  - Different definition of “mastery”:
    - 50%, 75% or 90% of children?
    - Mastery at initial and final position?
  - Word positions included:
    - Did they examine intervocalic position?
    - Did they test clusters?

Consonant Clusters

- Usually later developing than singleton consonants.
- A frequent therapy target; a problem for some second language learners.
- Suggests that they may be more difficult to produce than singletons.

Consonant Clusters

- Sampling mode may be crucial.
- A recent study suggests that omission of one element of a cluster is more likely in conversational speech than in single word tests.
- Single word tests may be less likely to identify a problem with clusters.

Consonant Clusters

- McLeod, van Doom & Reed (2001) concluded:
  - 1. Word-final clusters probably are acquired earlier than word-initial clusters.
    - Acquisition is probably aided by the emergence of grammatical morphemes (plurals, past tense, etc.).
  - 2. Two element clusters (e.g., /sl/ /bl/ /tr/) are generally acquired before three element clusters (e.g., /str/ /skl/).

Consonant Clusters

- 3. Children acquire word-initial sequence in a typical sequence:
  - 1. Omit one member “blue” /blu/ → [bu]
  - 2. Substitute for one member “blue” /blu/ → [bu]
  - 3. Produce it fully correctly.
  - 4. Less consistency in the pattern of acquisition of word-final clusters.
Universal Order?

- Shriberg has proposed we group the 24 English consonants into "developmental sound classes":
  - Early 8: /m, b, j, n, w, d, p, h/
  - Middle 8: /t, ŋ, k, g, f, v, tʃ, dʒ/
  - Late 8: /ʃ, θ, s, z, ð, l, r, ʒ/
- Not everyone would agree even on this division.

Suppression of Processes

- A different overall perspective is to look at how natural phonological processes are suppressed over time by children.
- If "phonological processes" are truly natural, and development involves the suppression of them, we should see a pattern across children.

Errors and Development

- Normative Data from Photo Articulation Test

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:0</td>
<td>25 +/- 13</td>
<td>20 +/- 10</td>
</tr>
<tr>
<td>3:6</td>
<td>16 +/- 10</td>
<td>15 +/- 12</td>
</tr>
<tr>
<td>4:0</td>
<td>16 +/- 14</td>
<td>14 +/- 11</td>
</tr>
<tr>
<td>4:6</td>
<td>14 +/- 11</td>
<td>11 +/- 10</td>
</tr>
<tr>
<td>5:0</td>
<td>9 +/- 11</td>
<td>9 +/- 10</td>
</tr>
<tr>
<td>5:6</td>
<td>7 +/- 7</td>
<td>7 +/- 8</td>
</tr>
<tr>
<td>6:0</td>
<td>6 +/- 6</td>
<td>5 +/- 8</td>
</tr>
</tbody>
</table>

Whole-Word Accuracy and Development

- From Schmitt, Howard, & Schmitt (1983)

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>% Words fully correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:0</td>
<td>68.5 +/- 10.3</td>
</tr>
<tr>
<td>3:6</td>
<td>76.4 +/- 10.7</td>
</tr>
<tr>
<td>4:0</td>
<td>80.0 +/- 10.3</td>
</tr>
<tr>
<td>4:6</td>
<td>83.8 +/- 5.5</td>
</tr>
<tr>
<td>5:0</td>
<td>88.0 +/- 6.0</td>
</tr>
<tr>
<td>5:5</td>
<td>88.7 +/- 7.8</td>
</tr>
<tr>
<td>6:0</td>
<td>91.9 +/- 4.9</td>
</tr>
<tr>
<td>7:0</td>
<td>95.4 +/- 2.1</td>
</tr>
</tbody>
</table>

Intelligibility and Development

- From Weiss, Gordon & Lillywhite (1987)

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>% Intelligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>25%</td>
</tr>
<tr>
<td>24</td>
<td>50%</td>
</tr>
<tr>
<td>30</td>
<td>64%</td>
</tr>
<tr>
<td>36</td>
<td>80%</td>
</tr>
<tr>
<td>42</td>
<td>92%</td>
</tr>
<tr>
<td>48</td>
<td>100%</td>
</tr>
</tbody>
</table>

Intelligibility and Development

- Caplan & Gleason surveyed parents of 235 children asking how much strangers understood of their child's speech.
- Used the data to create clinical cutoffs of the age when 90% of children reached particular milestones.
### Intelligibility and Development

- Understand 50%? 22 months
- Understand 75% 37 months
- Understand 100% 47 months
- Closely agree with Weiss et al. data.

### Intelligibility and Development

- Useful approximate index:
  - Expected % intelligible = Age in years divided by 4.

### The School-Age Child

- Much less studied than the preschool period.
- Most of the data comes from normative studies for the published single-word articulation tests (e.g., PAT).
- These data and the cross-sectional studies all suggest that the period of normal speech-sound acquisition ends at around 9;0 (may still see problems with clusters).

### The School-Age Child

- Very little is known about the acquisition of other aspects of phonology though much of it appears to be mastered during the school-age period.
  - Allophonic rules.
  - Morphophonemic rules.
  - N-V alternations, vowel shifts etc.