Learning how to learn: The acquisition of stress-based word segmentation strategies by infants

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Two classes of word boundary cues

Auditory/speech cues
- Words in isolation
- Utterance-edge words
- Allophonics
- Phonotactics
- Lexical stress
- etc.

Sequential statistical cues
- Distributions around known words
- Distributions of sounds (e.g., transitional probabilities between syllables)
- etc.

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Sequential statistical cues
(e.g., transitional probabilities)
- Useful for word segmentation at 8 months
- Domain-general learning mechanism: speech, tones, shapes, actions, etc.
- Species-general learning mechanism: tamarin monkeys, rats...
- Available by 2 months of age (visual tasks)
- Mechanism available at the outset of language acquisition, not tied to the structure of the infants’ native language. No prior learning needed.
Auditory/speech cues: Lexical stress

- Useful for word segmentation at 8 months:
  - English-learners expect words to be trochaic (strong-weak)
  - Quebec French learners expect words to be iambic (weak-strong)
- **Not** used by infants at 6 months
- Some learning about the native language required
- Supersedes use of statistical cues when mastered
  - **Mechanism not available at the outset of language acquisition, because it is tied to the structure of the infants' native language. Prior learning needed!**

How do sequential statistics and lexical stress mutually inform one another?

**Cue-conflict method** (following Johnson & Jusczyk, 2001): place statistics and stress in conflict, and examine the developmental trajectory of cue usage

General Method

- Create two artificial languages
  - Both contain the same bisyllabic “words”: dapu, dobi, bugo, diti
  - Manipulate stress cues (amplitude, duration, pitch)
  - In the “Trochaic” language, words contain first-syllable stress: DApU, DObi, Bugo, DIti
  - In the “Iambic” language, words contain second-syllable stress: daPU, doBI, buGO, dITi
- Synthesize a continuous stream of these words in random order, with no additional cues

**Test:** Segmentation choices indicate which cues infants are using

- Measure listening times for “words” vs. “part-words” (bisyllables spanning word boundaries)
  - Headturn Preference Procedure
  - Test items presented unstressed
- Which items babies consider to be “words” depends on whether they use a trochaic stress strategy or a statistical strategy:
  - If infants are using stress cues, then strong-weak sequences are “words”
  - If infants are using statistical cues, then statistically-probable sequences are “words”

Predictions

- If infants use stress cues, then strong-weak sequences are “words”
  - Expect **different** preferences for words vs. partwords in the Trochaic condition vs. the Iambic condition
- If infants use statistical cues, then statistically-probable sequences are “words”
  - Expect the **same** preferences for words vs. partwords in the Trochaic condition vs. the Iambic condition

Results are a function of age

- 6.5-month-olds show the same pattern of preferences for words & part-words, regardless of the placement of stress cues:
  - **Use of statistical cues**
- 9-month-olds shift their pattern of preferences for words & part-words as a function of the placement of stress cues (missegment iambic speech)
  - **Use of stress cues**

- **Both groups segment speech, but employ different strategies as a function of age**
What changed between 6.5 and 9 months of age?

**Hypothesis:** Infants have learned some words
- Infants initially use statistical cues (don’t need native language knowledge for segmentation)
- Once a small corpus has been segmented, stress patterns in the native language become apparent
- Infants can then begin to use a stress-based strategy, which is presumably more efficient

Testing the hypothesis: Can we give English infants an iambic bias?
- 9-month-old infants in two conditions
  - Infants first hear “pattern-induction” materials
    - List of bisyllabic trochaic nonsense words
    - List of bisyllabic iambic nonsense words (each list = 30 words, repeated twice)
  - Infants then hear the fluent speech from the prior experiment (different words from pattern induction)
    - Iambic induction + Iambic segmentation (Experimental)
    - Trochaic induction +Trochaic segmentation (Control)

Thiessen & Saffran (submitted)

Results
- **Without pattern induction** (Thiessen & Saffran, 2003): Different pattern of results for iambic and trochaic fluent speech
  - Missegment iambic speech: daPU, doBI → PUdo
- **With pattern induction**: Same results for iambic and trochaic fluent speech
  - Infants do not missegment iambic speech
  - Correctly treat iambs as words in iambic condition

Learning a new strategy
- 60 words heard during pattern induction led infants to abandon existing trochaic stress strategy, & instead begin to use iambic stress cues.
- Results replicate with 80% iambic words
  - Probabilistic cue rather than deterministic
- Results replicate when pattern induction words are presented in quasi-fluent speech, with no pauses but only coarticulation cues present to demarcate word boundaries

But what was actually learned?
- Infants may have induced an iambic stress strategy
- Or infants might have learned to **ignore** stress, and focus on statistical cues instead
  - Stress seen as unreliable after the iambic exposure
  - Using just statistics would account for the pattern of data that we observed in the iambic-iambic vs. trochaic-trochaic conditions
- We can tease apart these explanations by giving pattern-induction experience to younger infants

Method: 6.5-month-olds (usually use statistics)
- All infants first heard the iambic pattern induction materials
  - Can we induce an iambic segmentation bias?
- Infants then heard one of two segmentation languages
  - Iambic segmentation language
  - Trochaic segmentation language
- Test items: words and part-words

Predictions
- If attending to statistics (as they do in the absence of pattern induction materials): Same pattern of preferences across segmentation stress-type conditions
- If attending to stress: Different pattern of preferences
Results

• Different pattern of preference after iambic vs. trochaic segmentation materials \textcolor{blue}{\Rightarrow \textbf{suggests use of stress cues}}

• After iambic exposure, infants treat iambs as “words”, behaving as though they possess an iambic bias

• They missegment trochaic speech: \textbf{DApu, DObi} \textcolor{blue}{\Rightarrow \textbf{puDO}}

• 6.5-month-old infants are using stress cues instead of statistical cues, which is not what we observed in the absence of the pattern induction materials

Babies are smart listeners

• Developed new strategies over a few months given natural exposure (6.5- to 9-month-olds)

• Changed strategies after a few minutes of massed exposure (9-month-olds)

• Induced a new strategy after a few minutes of massed exposure (6.5-month-olds)

Interactive system of knowledge: Cascading effects of experience

\textbf{Auditory/speech cues}

• Words in isolation
• Utterance-edge words
• Allophonics
• Phonotactics
• \textbf{Lexical stress}
• etc.

\textbf{Sequential statistical cues}

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• etc.

Learning how to learn

• Infants begin with a set of “factory-installed” learning mechanisms, which operate over infants’ initial perceptual units.

• Continual reanalysis suggests other perceptual units that may be relevant
  – e.g., infants perceive stress long before they use stress

• New strategies emerge, which lead to the discovery of previously unobserved structures in the input

• A potent combination of power and flexibility!

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