Are infants sensitive to anticipatory coarticulation during word recognition?

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Sept. 12, 2014, 19th Mid-Continental Phonetics & Phonology Conference

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Overview

- Developmental Phonetics
- Crash course in eyetracking methods
- Coarticulation: Adult findings
- Current study
  - Can 18-24 month-olds take advantage of coarticulation during word recognition?
- Discussion

Developmental Phonetics

- Language acquisition
  - What do young children know about language?
  - How do they acquire this knowledge?
- Developmental phonetics
  - Acquisition of perceptual, acoustic, articulatory aspects of language
- Lexical processing
  - What do novice word-learners know about their first words?

Production lags behind comprehension

- Toddlers (and late talkers) cannot tell us what they know.
  - Studying language based on spoken language underestimates linguistic knowledge.
- Too young to follow complex or metalinguistic directions.
- Need to be creative: Habituation studies, head-turn studies, and others.
  - This is how we draw inferences about babies losing nonnative sound contrasts at 8 months, for example.
- One method: **eyetracking**

Eyetracking

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Methodology

- "Visual world" or "looking while listening" paradigms
  - Put some images or printed words onscreen.
  - An audio prompt to view one of the images.
  - Eyetracker records where the subject fixates.
- Measure of real-time language processing.
- How does the child's gaze change as the sentence unfolds?

Slide 1

Not a new method

COGNITIVE PSYCHOLOGY 6, 84–107 (1974)

The Control of Eye Fixation by the Meaning of Spoken Language

A New Methodology for the Real-Time Investigation of Speech Perception, Memory, and Language Processing
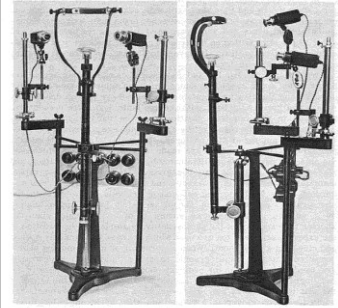
ROGER M. COOPER[1,2]

Stanford University

Slide 2

Fig. 21. The apparatus used in recording eye movements.

http://en.wikipedia.org/wiki/File:Yarbus_eye_tracker.jpg

Slide 3

What does an eye-tracking experiment look like?

Video of experiment with eyetracking data overlaid on computer screen.

Yellow dot is current gaze location.

Red trail shows last 500ms

Slide 4

What do eyetracking data look like?

X: Time relative to target onset

Y: Proportion of looking to target (Accuracy)

Slide 5
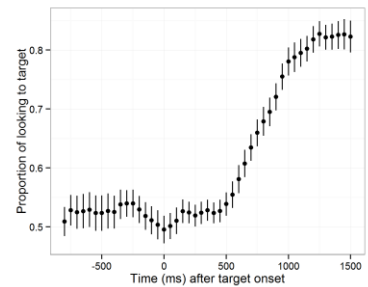
Coarticulation

Coarticulation

Slide 6

Coarticulation

• Fluent speech is continuous, so that nearby sounds overlap and influence each other.
  • Vowel nasalization: ham: [hæ̃m]
  • keep vs. coop: [k̟]eep
  • she vs shoe: [ʃʷ]oe
  • Place assimilation:
    • Input: i[m]put
    • in case: i[ŋ] case
    • green boat: gree[m] boat
  • the[d] dog vs. the[b] ball

• Adults can take advantage of these regularities during lexical processing.

Slide 1

Adults look to *gree*[m] *boat* sooner than *gree*[n] *boat*
Gow & McMurray (2007)

A: target

Slide 2
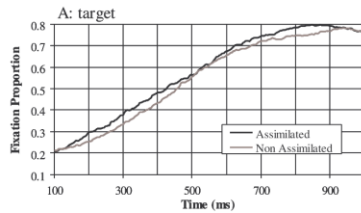
Adults look to *the*[I] *ladder* sooner than *the*[ə] *ladder*

Salverda, Kleinschmidt, & Tanenhaus (2014)

"With these stimuli, effects of speech on eye-movement control began about **70 ms** earlier than in Experiment 1, suggesting rapid use of anticipatory coarticulation."

Slide 3

Current Study

## Slide 4
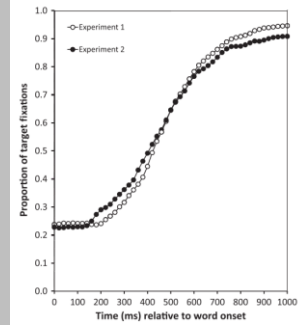
Burning question

- Can toddlers use acoustic information in the word "the" to anticipate the following noun?
- Eight month-old infants use coarticulatory cues in word segmentation (Johnson & Jusczyk, 2001)
- We can learn something about:
  - Processes behind word recognition and context integration
  - Mental representations of speech sounds and early words

Slide 5

Participants

- 30 participants, 16 boys and 14 girls
- Mean age: 21 months, range: 18-24 months
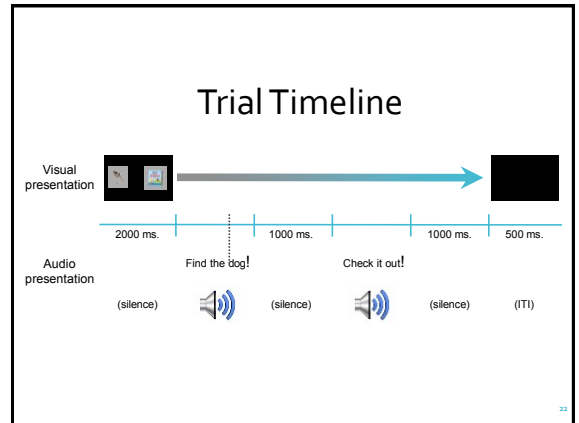
Slide 6

Stimuli

- Word pairs
  - Experimental trials in yoked pairs: *duck/ball, dog/book.*
  - Filler trials to maintain interest (e.g. *soup/shoes*)
- Manipulated Coarticulation
  - Cross-spliced all stimuli:
    - "the" tokens from "the book", "the dog", "the hut"
  - Neutral cues: *the*[ə] *dog/book*
  - Facilitating cues: *the*[d] *dog*, *the*[b] *book*

Stimuli
F₁ and F₂ formant transitions
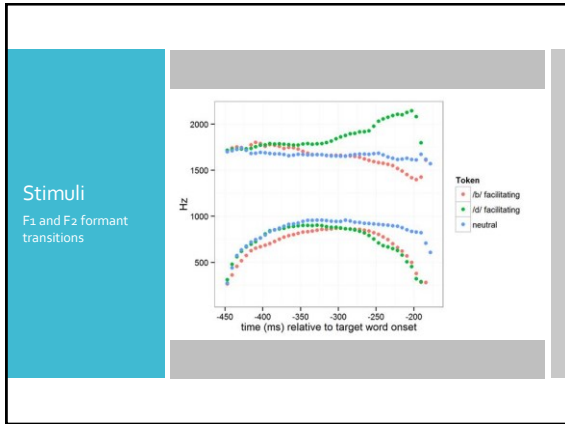
Stimuli

Find the duck (facilitating)

Find the duck (neutral)

See the ___ (facilitating)

See the ___ (neutral)

Find the (facilitating)

Procedure

- Conditions
  - Facilitating (8 trials)
  - Neutral (8 trials)
  - Fillers (7 trials)
- Two blocks
- Looking-while-listening format
  - Two images presented on screen
  - One image is target, other is distractor.
  - Target words presented in carrier phrases (e.g., *find the dog*).

Trial Timeline

Visual presentation				
	2000 ms.	1000 ms.	1000 ms.	500 ms.
Audio presentation	Find the dog!	Check it out!		
	(silence)	(silence)	(silence)	(ITI)

Predictions

- Three different possibilities:
- 1. Toddlers are not sensitive: Curves don't differ across conditions
- 2. Sensitive like adults: Head start, but similar shaped curves
- 3. More sensitive than adults: Curves have different slopes (i.e., different processing speeds)

Slide 1
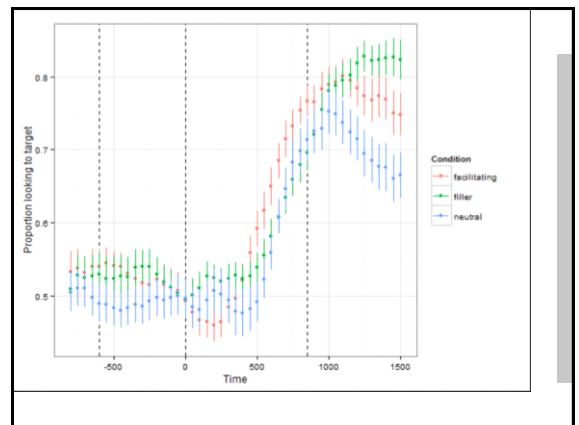
Analytic Strategy

- Growth Curve Analysis (Barr, 2008; Mirman, 2014)
  - Restrict analysis to a meaningful window of time
  - Model how fixations to target change as a function of time and condition.
- Empirical Logit Transformation
  - Proportions are bounded between [0,1].
  - Transform to empirical log-odds, so models work
  - $\log\left(\frac{\text{to target}+0.5}{\text{to distractor}+0.5}\right) = \beta_0 + \beta_1 t + \beta_2 t^2 + \text{etc}$
- Mixed Effects Regression
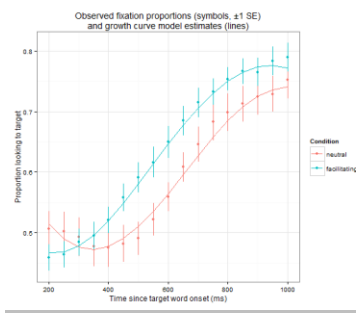 - Random effects for subjects and subjects x condition

Slide 2

Analysis Window

Zoomed in window

Transformed Proportions

Slide 3
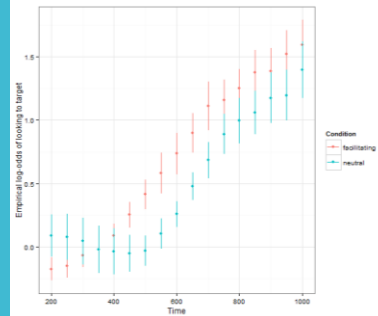
Results

Significant effect of condition

Nonsignificant interaction between condition and slope

Roughly, 100 ms head-start from coarticulation

Slide 4

Discussion

- Toddlers looked to target approximately 100 ms sooner when they heard facilitating coarticulation cues on "the".
  - In other words, cues gave them a head-start.
- The non-significant effect of condition on the linear time term means that the average slope of the curves did not differ significantly between conditions.
  - In other words, they did not process the words more rapidly. Just earlier.

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Next steps

- How do toddlers do when the target word is not presented at all?
  - Find the _____
- How do younger children perform?
- Is there an effect of age or vocabulary size on access to anticipatory coarticulation?
- Use different sounds
  - Much more coarticulatory information for /d/ rather than /b/.
  - /g/ or /m/? (Limited by the words familiar to toddlers)

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Rethinking Coarticulation

- We might think of coarticulation as an obstacle to speech perception
  - Fewer perceptual invariants to latch onto.
- But coarticulatory variability adds coherence to speech signal.
  - Nearby sounds are more alike.
  - Can support word recognition.
- Much evidence for this view of coarticulation in the adult literature.
- This study is the first evidence that toddlers can use anticipatory coarticulation during word recognition.
  - Process cues as they arrive.
  - Daring interpretation: Show gradient lexical activation from the earliest stages of word learning.

Acknowledgements

waisman.wisc.edu/
infantlearning/

learningtotalk.org