Listener Bias in Categorical and Continuous Measures of Children’s Fricatives

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Abstractness and Specificity

- The sound structure of language encompasses representations in multiple sensory domains and at multiple levels of abstraction away from raw sensory experiences
- Acquisition happens in all of these domains and processes

Continuous Differentiation in Development

- Li (2012): the differentiation of /s/ from /ʃ/ centroids between 30 and 60 months is continuous, and extends beyond the point at which these sounds are transcribed to be correct

Measuring Children’s Productions

/k/ before front vowels in Greek:
- Greek speakers mostly hear correct /k/
- English speakers mostly hear [t] substitution
- Japanese mostly hear [tʃ] substitution

<table>
<thead>
<tr>
<th>/k/pos</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency (Hz)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>target</td>
</tr>
<tr>
<td>Greek</td>
</tr>
<tr>
<td>English</td>
</tr>
<tr>
<td>Japanese</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
</tr>
<tr>
<td>target</td>
</tr>
<tr>
<td>Greek</td>
</tr>
<tr>
<td>English</td>
</tr>
<tr>
<td>Japanese</td>
</tr>
</tbody>
</table>
Visual Analog Scaling

- An alternative: Visual Analog Scaling (VAS) used at least as early as Massaro & Cohen, 1983) to probe adult perception continuously.

  - Participant responds by clicking on the line (a visual analog to the number line, with a neutral midpoint and seemingly infinite variation to the idealized endpoints)
  - Used in a variety of recent studies (Bernstein, Johnson, Beckman, Edwards, & Munson, 2015; Julien & Munson, 2012; Munson, Johnson, & Edwards, 2012; Munson, Schellinger, Edwards, Beckman, & Meyer, 2010; Schellinger, Munson, & Edwards, 2015)

200 CV sequences from single-word productions of English-speaking children, aged 2 through 5 years.

- correct /s/
- [s] for /θ/
- intermediate: [s:θ]
- Intermediate: [θ:s]
- [θ] for /s/
- correct /θ/

VAS Ratings are Related to Acoustics

- VAS ratings differentiate among more transcription categories than traditional binary systems do.
- Provides evidence for covert contrasts
You’ve Heard this all Before

• I have been presenting work on VAS ratings of children’s speech for the last seven years.
• Today’s new takes:
  – Why are some people more categorical than others?
  – Is it less susceptible to bias than binary measures are?

Degree of Categoricity

Data from Munson & Urberg-Carlson, in prep, data from an “s”-“sh” VAS

Maddeningly Hard to Measure

• Traditional measures of categoricity (like Probit analyses) don’t work, as the continua vary in multiple acoustic dimensions
• This is going to require some creativity with measurement.

Attention to continuous vs categorical detail

• Can we change the categoricity of someone’s VAS responses by constructing an experiment that draws attention either to categorical detail or to continuous variation?
Drawing Attention

- The general design: interleave VAS ratings of children's /s/ and /θ/ productions on a “s” to “th” scale with judgments of a continuous variable (gender typicality) or a categorical variable (what vowel the child produced).

Experiment Design

- Two blocks: one randomly interleaved /s/-/θ/ ratings with gender judgments, one randomly interleaved it with vowel judgments.
  - Order of the blocks randomized.
  - Listeners never knew what ratings they were making until the stimulus was done playing.
  - Each block had 200 stimuli, the same as in Schellinger et al. (2015).

Schematic View of the Experiment

Stimuli

- Children aged 2-5 acquiring English.
- Fricatives in initial position, either an /s/ or a /θ/ target.
- Transcribed as either, [s], [θ], [s:θ], or [θ:s].
- Varied the acoustic parameters relevant for the /s/-/θ/ contrast.
Analysis 1: Distributions

- Density Mixture Modeling in `mclust`
  - Did the conditions differ in the shape of the response distributions?
    - No

Analysis 2: Differentiation

- Did the conditions differ in how many transcription categories they differentiated among?
  - No

Analysis 3: Acoustics

- Did the conditions differ in how strongly the responses were affected by the relevant acoustic characteristics of the fricatives (m1, m2, intensity relative to the following vowel)?
  - No

|                  | Estimate | Std.Error | df  | t value | Pr(>|t|) |
|------------------|----------|-----------|-----|---------|----------|
| (Intercept)      | 4.164e-01| 2.032e-02 | 21  | 20.490  | <0.0001 *** |
| M1, middle 40 ms | -6.865e-02| 6.207e-03 | 26  | -11.060 | <0.00001 *** |
| M2, middle 40 ms | 2.849e-02 | 4.757e-03 | 21  | 5.991   | <0.00001 *** |
| F2 at vowel onset| -7.669e-03| 4.244e-03 | 21  | -1.807  | 0.085    . |
| F0 at vowel midpoint| 2.156e-02| 4.073e-03 | 23  | -5.294  | <0.00001 *** |
| Duration         | 3.383e-02 | 3.965e-03 | 40.7| 8.532   | <0.00001 *** |
| Relative Intensity| -1.084e-01| 9.963e-03 | 22  | -10.877 | <0.00001 *** |

Interim Conclusion

- VAS ratings are impervious to whether they are paired with a task that asks people to rate gender or one that asks them to rate the vowel that they heard.
Is it VAS or the Experiment?

- Is VAS impervious to bias, or does this particular experimental manipulation simply not bias responses?

Redo the Experiment

- We redid the experiment with a new set of listeners. It was identical in all ways except one: listeners made a binary response of whether they heard “s” or “th” rather than a VAS judgment.

- Binary judgments in both conditions differentiated among all six transcription categories

Logit Mixed-Effects Model: Acoustics

- The two conditions differed in the weighting that listeners gave to the stimuli

|                           | Estimate   | Std.Error   | z value | Pr(>|z|) |
|---------------------------|------------|-------------|---------|----------|
| (Intercept)               | 0.451709   | 0.104600    | -4.318  | <0.0001 *** |
| M1, Middle 40 ms          | -0.985314  | 0.053929    | -18.270 | <0.0001 *** |
| M2, Middle 40 ms          | 0.598601   | 0.046904    | 12.762  | <0.0001 *** |
| F2 at vowel onset         | -0.150684  | 0.038941    | -3.870  | 0.0001 ***  |
| F0 at vowel midpoint      | -0.340250  | 0.040636    | -8.373  | <0.0001 *** |
| Duration                  | 0.373812   | 0.045587    | 8.200   | <0.0001 *** |
| Relative Intensity        | -1.312905  | 0.063463    | -20.688 | <0.0001 *** |
| M1 by Condition           | 0.142988   | 0.048544    | 2.946   | 0.0032 **   |
| Midpoint F0 by Condition  | 0.093393   | 0.040295    | 2.318   | 0.0204 *    |

Logit Mixed-Effects Model: Acoustics

- If you convert the data from Experiment 1 to binary responses and do the same analysis, the acoustics do not differ as a function of experiment.

|                           | Estimate   | Std.Error   | z-value | Pr(>|z|) |
|---------------------------|------------|-------------|---------|----------|
| (Intercept)               | -0.67810   | 0.18076     | -3.751  | 0.000176 *** |
| M1, middle 40 ms          | -0.58186   | 0.06084     | -9.564  | <0.000001 *** |
| M2, Middle 40 ms          | 0.30108    | 0.05209     | 5.780   | <0.000001 * ** |
| F2 at Onset               | -0.07477   | 0.04100     | -1.824  | 0.068195 .  |
| F0 at Midpoint            | -0.27981   | 0.04143     | -6.754  | <0.000001 *** |
| Duration                  | 0.29393    | 0.04293     | 6.848   | <0.000001 *** |
| Relative Intensity        | -1.14442   | 0.09497     | -12.050 | <0.000001 *** |
Logit Mixed-Effects Model: Acoustics

• In the gender condition, listeners weighted $m_1$ more strongly than they weighted it in the vowel condition.
• In the gender condition, listeners attended to $f_0$ when making judgments; in the vowel condition, they did not.

Conclusion

• VAS ratings are more stable than binary ratings to the bias introduced by mixing listener ratings with ratings of continuous or categorical responses.
• Bias is introduced at the decision stage, not in the encoding stage.

Future Work

• Look at other, more conventional ways of biasing responses:
  – Long- versus short-lag responses (as in Babel & Johnson, 2010)
  – Priming a bimodal or unimodal distribution (as in Clayards et al., 2008)
    • Re-analyzing these data to determine whether the condition effects are really just response-latency effects.

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References


