PREDICTORS OF INTRA-WORD VARIABILITY IN TYPICALLY DEVELOPING PRESCHOOLERS
INTRA-WORD VARIABILITY

- Characteristic of:
  1. **Childhood apraxia of speech**: “inconsistent errors on consonants and vowels in repeated productions of syllables or words” (ASHA, 2007, p. 2)
  2. **Phonological impairment**: “children producing 10 or more of the 25 words differently (> 40%), on at least two of the three occasions that they are elicited, should be classified as having inconsistent disorder” (Dodd & Crosbie, 2005, p. 152)
  3. **Typical development**: McLeod and Hewett (2008); Macrae (2013); Sosa and Stoel-Gammon (2012)
RATES OF INTRA-WORD VARIABILITY

1. Childhood apraxia of speech: very little published data; 56-88% variability in 3 children aged 4;6-7;7 (Marquardt et al., 2004); 100% variability in 16 Hebrew-speaking children aged 2;7-5;6 (Tubul-Lavy, 2012)

2. Phonological impairment: 15-79% ($M = 41\%$) in children aged 3;6-5;5 (Macrae et al., 2014); 40% or higher reflects “inconsistent disorder” (Dodd & Crosbie, 2005)

3. What about typical development?
   - 50-100% ($M = 78\%$) in children aged 1;9-3;1 (Macrae, 2013); 56-94% ($M = 76\%$) in children aged 2;0 (Sosa & Stoel-Gammon, 2012); 48-76% ($M = 67\%$) in children aged 2;5 (Sosa & Stoel-Gammon, 2012); 42-78% ($M = 53.7\%$) in children aged 2;0-3;4 McLeod & Hewett (2008)
   - However, Holm et al. (2007)...
RATES OF INTRA-WORD VARIABILITY

% Variability (Holm et al., 2007)

- 0-3:5: 12.96%
- 3:6-3:11: 12%
- 4:0-4:5: 6.91%
- 4:6-4:11: 5.31%
- 5:0-5:5: 4.19%
- 5:6-5:11: 2.88%
- 6:0-6:11: 2.58%
In addition to Holm et al. (2007), one study has documented rates of intra-word variability in children with typical development older than 3½ years. deCastro & Wertzner (2011) found 9.8% intra-word variability in Brazilian Portuguese speaking children from 5;0-10;10 (M age not reported) (considerably higher than 2.95% for 6-year-olds in Holm et al., 2007).

Has intra-word variability mostly resolved by 4 years old?

Researchers must first document rates of intra-word variability in children with typical development before clinicians can use rates to diagnose SSDs and their subtypes.
RESEARCH AIM #1

To document rates of overall intra-word variability and subtypes of variability in 2½- to 4-year-old children with typical speech and language development and to compare rates obtained from two different research sites.
CONTRIBUTORS TO INTRA-WORD VARIABILITY

Word-specific factors:
1. Phonological complexity (Macrae, 2013; Sosa & Stoel-Gammon, 2012)
2. Word frequency (Sosa & Stoel-Gammon, 2012)
3. Neighborhood density (Sosa & Stoel-Gammon, 2012)

Child-specific factors:
1. Age (Macrae, 2013)
2. Expressive vocabulary (Macrae, 2013; Sosa & Stoel-Gammon, 2012)
CONTRIBUTORS TO INTRA-WORD VARIABILITY

- Children in these studies were aged 3;1 or younger
- What about older children?
- Each of these studies had 15 participants
- What about a larger group of children?
- What about other child-specific factors, like speech sound production and receptive language abilities?
RESEARCH AIM #2

Explore potential concurrent predictors of intra-word variability, including age, expressive and receptive vocabulary, and speech sound production abilities, in 2½- to 4-year-old children with typical speech and language development.
PARTICIPANTS

- 43 children (19 male, 24 female) aged 2;6-4;2 ($M=3;3$) with typical speech and language development
- 34 children from Arizona; 9 from Florida
- All children administered Goldman-Fristoe Test of Articulation (GFTA-2), Expressive Vocabulary Test (EVT-2), Peabody Picture Vocabulary Test (PPVT-4), and Inconsistency Assessment (IA)
  - EVT mean standard score = 117 (s.d. = 12.7)
  - PPVT mean standard score = 114 (s.d. = 13.3)
  - GFTA mean standard score = 108 (s.d. = 10.4)
INCONSISTENCY ASSESSMENT

- 25 1-4 syllable words elicited 3 times each using pictures and objects within the same session (trials separated by another activity)
- Target words coded as variable if any differences in broad transcription (consonants and vowels) across 3 productions
- Percent variability calculated as # target words produced variably divided by total # target words (< 25 for some participants)
- Percentages also calculated for the following subcategories: consistent correct (CC), consistent incorrect (CI), variable with hits (VH), variable no hits (VN) (see Grunwell, 1992; Holm et al., 2007)
CONSENSUS TRANSCRIPTION

- IA transcribed using consensus transcription procedure similar to Shriberg et al. (1984) (majority of 17 consensus rules used)
  - Transcriptions for Arizona cohort were made from audio-video recordings
  - Transcriptions for Florida cohort were made from audio-only recordings
- Research assistants (RAs) were undergraduate or graduate majors in CSD with a particular strength in IPA transcription
- RAs received additional training in IPA transcription for the present study with first or second author
Training involved transcribing IA responses from children not participating in the present study (Florida) or by transcribing responses from the GFTA (Arizona).

Research assistants transcribed each production independently. RAs then compared transcriptions and discussed disagreements. In most cases, disagreements resolved. In other cases, first or second author served as tie breaker.
Research Aim #1 (rates of intra-word variability): descriptive statistics for overall variability and subcategories for all participants and Mann-Whitney U tests comparing rates across research sites (AZ and FL)

Research Aim #2 (predictors of intra-word variability): standard linear regression used to determine which child-specific factors, if any, among age (in months), speech sound production abilities (GFTA-2 raw score), expressive vocabulary (EVT-2 raw score), or receptive vocabulary (PPVT-4 raw score) predicted intra-word variability (% variability from IA)
RESULTS
COMPARING THE TWO COHORTS

- Independent samples Mann-Whitney U Test
  - Mean age of the groups does not differ (Florida $M = 42$ months; Arizona $M = 38$ months)
  - Groups do not differ on vocabulary or articulation test STANDARD scores
  - Groups do not differ on proportion of words produced variably on the IA
  - Florida cohort has higher EVT raw scores than Arizona cohort ($p=.01$)
  - Florida cohort has lower GFTA raw scores than Arizona cohort ($p=.04$)
    (i.e., Florida cohort had fewer errors on target consonants)
For all children, mean proportion of words produced variably was 68% (s.d. = 16.5; range = 32%-100%)
- Florida cohort = 70%; Arizona cohort = 68%
RESULTS
RESEARCH AIM #1: RESPONSE TYPE FOR EACH COHORT

Arizona cohort (n=34)
- Variable 'with hits': 23%
- Variable 'no hits': 45%
- Consistent correct: 20%
- Consistent incorrect: 12%

Florida cohort (n=9)
- Variable 'with hits': 44%
- Variable 'no hits': 27%
- Consistent correct: 25%
- Consistent incorrect: 13%
RESULTS

RESEARCH AIM #2: PREDICTORS OF VARIABILITY

- Standard multiple regression with proportion of words produced variably (IA) as outcome measure
  - Predictor variables include:
    - Age (in months)
    - EVT raw
    - PPVT raw
    - GFTA raw

Correlations between variability and all predictor variables

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>EVT</th>
<th>PPVT</th>
<th>GFTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variability</td>
<td>-0.458**</td>
<td>-0.610**</td>
<td>-0.493**</td>
<td>0.442**</td>
</tr>
</tbody>
</table>

**p<.01
RESULTS
RESEARCH AIM #2: PREDICTORS OF VARIABILITY

Model summary: $R^2 = .436$, $R^2_{\text{adj}} = .375$, $F(4,37) = 7.16$, $p < .001$

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$\beta$</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in months)</td>
<td>-.001</td>
<td>-.022</td>
<td>-.131</td>
<td>.897</td>
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<tr>
<td>EVT</td>
<td>-.006</td>
<td>-.628</td>
<td>-2.739</td>
<td>.009*</td>
</tr>
<tr>
<td>PPVT</td>
<td>.000</td>
<td>.049</td>
<td>.246</td>
<td>.807</td>
</tr>
<tr>
<td>GFTA</td>
<td>.001</td>
<td>.090</td>
<td>.579</td>
<td>.566</td>
</tr>
</tbody>
</table>
68% of words produced with some variability (similar rates obtained at both research sites)

Variable ‘no hits’ was the most frequent response type (41%); followed by variable ‘with hits’ (27%), consistent correct (21%), and consistent incorrect (12%)

Variability is significantly correlated with age, expressive vocabulary, receptive vocabulary, and articulation ability

When all variables are entered into a regression model, expressive vocabulary is the only significant predictor of variability, accounting for 38% of the variance
RESULTS
ADDITIONAL ANALYSIS

- Correlations among child factors and different response types

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>EVT</th>
<th>PPVT</th>
<th>GFTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>V 'with hits'</td>
<td>.163</td>
<td>.260</td>
<td>.267</td>
<td>-.628**</td>
</tr>
<tr>
<td>V 'no hits'</td>
<td>-.475**</td>
<td>-.663**</td>
<td>-.562**</td>
<td>.797**</td>
</tr>
<tr>
<td>C Correct</td>
<td>.489**</td>
<td>.621**</td>
<td>.588**</td>
<td>-.669**</td>
</tr>
<tr>
<td>C Incorrect</td>
<td>.233</td>
<td>.229</td>
<td>.172</td>
<td>.038</td>
</tr>
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- In a regression model, EVT and GFTA are both significant predictors of rate of Variable ‘no hits’, accounting for 70% of the variance
- Only GFTA predicts rate of Variable ‘with hits’ responses (42% of variance accounted for)
Results are consistent with previous work (Macrae, 2013; McLeod & Hewett, 2008; Sosa & Stoel-Gammon, 2012), but very different from Holm et al., 2007

**Why?**
- Data collection site
- Transcription procedures

Need to rethink the idea that intra-word variability is not a characteristic of typical speech development (even in children as old as 4 years)

Given high rates of variability in typically developing young children, caution should be used in assuming that segmental variability necessarily indicates motor planning/programming deficits in children with speech sound disorder (see Goffman, Gerken, & Lucchesi, 2007)

Variable ‘no hits’ responses is common in children with typical speech development and does not necessarily reflect speech disorder, as has been suggested (Holm et al., 2005)
Further study is needed to describe the characteristics of intra-word variability in different populations and different age groups (e.g., typical development, phonological disorder, CAS)

- By different research teams
- Using different transcription methods
- Using different variability metrics
DISCUSSION

- What does the intra-word variability observed here reflect?
  - Lack of stable, segmental, phonological representations
    - Particularly Variable ‘no hits’ responses
  - Phonological working memory
    - Similar to Non-word repetition
  - Strategies used by children to get closer to the adult target

- Clinical applications of intra-word variability in the assessment of language and pre-reading development
CONCLUSION

- Work by a variety of different researchers at different data collection sites and often with different methods is arriving at the consensus that intra-word variability is prevalent in typically developing children as old as 4-years.
- Variable ‘with hits’ vs. variable ‘no hits’ does not appear to differentiate typical from atypical intra-word variability.
- Clinicians should use caution in using intra-word variability in the differential diagnosis of speech sound disorder with young children until we know more about the characteristics of variability in different clinical populations.
REFERENCES


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