THE ROAD TO UNDERSTANDING SPEECH MOTOR CONTROL IN CHILDREN WITH SPEECH SOUND DISORDERS

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HTI SEMINAR
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Our Approach

Speech motor development

- What can we learn about development of speech motor control through movement analysis?

- How is this feasible in young children?

- Combining kinematic, acoustic & perceptual information
speech sound disorders

Speech motor control in children with speech sound disorders

- Childhood apraxia of speech (CAS)
- Dysarthria
- Articulation/phonological impairments
CONTROVERSIES IN CAS?

Underlying deficit in CAS?

Speech & nonspeech characteristics associated with CAS?

Appropriate assessment & treatment procedures for children with CAS?
UNDERLYING DEFICIT IN CAS?

Planning, programming and/or execution of speech movements

EVIDENCE OF A MOTOR DEFICIT IN CAS

Increased within-subject variability in coarticulation patterns in CAS than controls (Nijland et al., 2002).

Larger kinematic stiffness values in tongue tip and LL in CAS than controls during oral closure (Terband et al., 2008).

Improved segmental accuracy over time accompanied by decreased duration and increased movement stability (Grigos and Kolenda, 2010).

Increased LL movement amplitude in both CAS and SD groups; higher variability of tongue tip movement trajectories in CAS than controls (Terband et al., 2011).
THEORETICAL PERSPECTIVE

DYNAMIC SYSTEMS APPROACH

Motor control and coordination

Relationship between internal & external factors
  • Self-organization
  • Rate limiters
NEWELL’S CONSTRAINT MODEL
(NEWELL, 1986)

Individual Constraints

Task Constraints

Environmental Constraints
How does speech motor control differ between children with speech sound disorders & children with typical speech and language development?

Speech Sound Disorders
  Subtype
    CAS
    SD
    TD
Controls
DEVELOPMENTAL CHANGES IN ORAL ARTICULATOR MOVEMENT

Duration: longer in children than adults

- Jaw (Grigos et al, 2005; Grigos, 2009)
- Lower lip (Goffman & Malin, 1999; Goffman & Smith, 1999; Smith & Goffman, 1998, Walsh et al, 2006)
- Tongue (Cheng et al, 2007)
DEVELOPMENTAL CHANGES IN ORAL ARTICULATOR MOVEMENT

Variability: decreases over the course of development

- Duration (Grigos et al, 2005; Sharkey & Folkins, 1985)
- Displacement (Sharkey & Folkins, 1985; Smith & McLean-Muse, 1986; Watkin & Fromm, 1984)
- Movement pattern variability (Goffman & Smith, 1999; Grigos, 2009; Smith & Goffman, 1998)
DEVELOPMENTAL CHANGES IN ORAL ARTICULATOR MOVEMENT

Coordination: improves with development

- UL & LL (Smith et al, 1995; Walsh et al 2006; Sasisekeran et al 2010)
- Tongue-tip/tongue-body (tongue palatal contact) (Cheng et al, 2007).
How do these skills develop in children with speech sound disorders?
Research Questions

1. Differences in oral articulator movement between CAS, SD, TD?
2. Differences in movement variability between CAS, SD & TD?
3. Differences in movement coordination between CAS, SD & TD?
4. Impact of word length on articulatory control?
METHOD
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean Age (Range)</th>
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<tbody>
<tr>
<td>CAS</td>
<td>11</td>
<td>4.5 (2.8 – 5.8)</td>
</tr>
<tr>
<td>SD</td>
<td>7</td>
<td>4.9 (3.3 – 6.9)</td>
</tr>
<tr>
<td>TD</td>
<td>24</td>
<td>5.2 (3.1 – 8.4)</td>
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</table>
ASSESSMENT

TASKS

Single word test of articulation/phonology
Spontaneous speech sample – 100 word
Real and nonword repetition tasks
Phrase/sentence repetition tasks
Single and multi-syllable sequencing tasks
Oral motor structure and function
ASSESSMENT

MEASURES

Consonant & vowel accuracy
Phonetic inventory
Phonological process analysis
Consistency
Segmentation
Lexical stress
Repetition tasks: rate and accuracy
OTHER AREAS TESTED

- Nonverbal cognition
- Receptive language
- Expressive language
- Hearing
DIAGNOSING CAS

ASHA position statement on CAS (ASHA, 2007)

Three characteristics:
- Inconsistent Errors
- Articulatory transitions
- Prosodic errors

Across contexts
- Single words
- Connected speech
- Repetition tasks

Other characteristics:
- Articulatory groping
- Metathetic errors
- Sequencing errors
- Vowel errors
- Timing errors
- Omissions/Distortions
- Reduced phonetic inventory
- Change with increase in linguistic complexity
- Progress in treatment

**PARTICIPANT PROFILES**

Inconsistency Sequencing Vowel Prosodic Slow Reduced Groping Errors Errors Errors Errors Progress Inventory

[Graph showing data points for Inconsistent Errors, Sequencing Errors, Vowel Errors, Prosodic Errors, Slow Progress, Reduced Inventory, Groping, representing different groups TD, SD, and CAS.]
EXPERIMENTAL SETUP
Oral Articulator Movement

Optical Tracking System (Vicon)

POP
PUPPET
PUPPYPOP

HTI Seminar March 16, 2012
PROCEDURE

Target words elicited during play
10-15 productions per word
Accurate productions selected for analysis

1 syllable
• pop

2 syllable
• puppet

3 syllable
• puppypop
ANALYSES

Transcription
PCC
PVC
PEC
Prosody

Kinematic
Duration
Displacement
Velocity
Variability
Coordination
Results
<table>
<thead>
<tr>
<th>Word Length</th>
<th>Group</th>
<th>PCC (%)</th>
<th>PVC (%)</th>
<th>PEC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 syllable</td>
<td>CAS</td>
<td>85.5</td>
<td>89.6</td>
<td>71.6</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>96.0</td>
<td>96.0</td>
<td>72.8</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>99.3</td>
<td>99.8</td>
<td>82.1</td>
</tr>
<tr>
<td>2 syllable</td>
<td>CAS</td>
<td>89.5</td>
<td>86.6</td>
<td>53.8</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>94.1</td>
<td>94.6</td>
<td>78.9</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>99.1</td>
<td>96.9</td>
<td>83.9</td>
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<tr>
<td>3 syllable</td>
<td>CAS</td>
<td>86.8</td>
<td>84.6</td>
<td>50.4</td>
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<tr>
<td></td>
<td>SD</td>
<td>96.8</td>
<td>100.0</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>96.4</td>
<td>98.5</td>
<td>95.7</td>
</tr>
</tbody>
</table>
RESEARCH QUESTIONS

1. Differences in oral articulator movement between CAS, SD, TD?

2. Differences in movement variability between CAS, SD & TD?

3. Differences in movement coordination between CAS, SD & TD?

4. Impact of word length on articulatory control?
MOVEMENT DURATION

- POP
- PUPPET
- PUPPYPOP

* = Main Effect of Group, p<.01
ORAL OPENING & CLOSING MOVEMENTS
Lip Aperture

Opening

Closing

pop  puppet  puppypop
pop  puppet  puppypop

= CAS           = SD             = TD

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**Research Questions**

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JAW STABILITY

- Main Effect of Group, p = .038
**INDIVIDUAL VARIATION - DURATION**

![Graph showing coefficient of variation for different groups](image)

**Legend:**
- **CAS**
- **SD**
- **TD**

**Groups:**
- **pop**
- **puppet**
- **puppy**

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MOVEMENT COORDINATION

Within Trial: Crosscorrelation between articulator pairs (Jaw-Lower Lip, Jaw-Upper Lip, Upper Lip-Lower Lip)
- Peak Correlation
- Lag

Across Trials: Repeatability of Movement Sequence
Lip Aperture
- Spatiotemporal Index (STI)
**Spatial Coupling: Peak Correlation**

**Main Effect of Length**  **No Group or Interaction Effect**

- **Jaw-Lower Lip**
  - F(2,15)=26.177, p<.0001

- **Jaw-Upper Lip**
  - F(2,15)=4.868, p=.015

- **Upper Lip-Lower Lip**
  - F(2,15)=9.629, p=.001

Moss & Grigos, in preparation
**TEMPORAL SYNCHRONY: LAG**

**MAIN EFFECT OF LENGTH**  **NO GROUP OF INTERACTION EFFECT**

---

**Jaw-Lower Lip**

- CAS
- SD
- TD

**Jaw-Upper Lip**

- CAS
- SD
- TD

**Upper Lip-Lower Lip**

- CAS
- SD
- TD

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F(2,15) = 3.745, p = .035

F(2,15) = 12.412, p < .0001

(Moss & Grigos, in preparation)
COEFFICIENT OF VARIATION: PC

MAIN EFFECT OF GROUP  NO LENGTH OR INTERACTION EFFECT

F(2,15)= 4.962, p=.022

(Moss & Grigos, in preparation)
COEFFICIENT OF VARIATION: PC

MAIN EFFECT OF GROUP NO LENGTH OR INTERACTION EFFECT

F(2,15) = 4.962, p = .022

(Moss & Grigos, in preparation)
Coefficient of Variation: Lag

Main Effect of Group

No Length or Interaction Effect

<table>
<thead>
<tr>
<th></th>
<th>POP</th>
<th>PUPPET</th>
<th>PUPPYPOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw-Lower Lip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaw-Upper Lip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Lip-Lower Lip</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- F (2,15) = 4.267, p = .034
- F (2,15) = 4.366, p = .032

(Moss & Grigos, in preparation)
COEFFICIENT OF VARIATION: LAG

MAIN EFFECT OF GROUP  NO LENGTH OR INTERACTION EFFECT

Jaw-Lower Lip

\[ F (2,15)=4.267, p=.034 \]

Jaw-Upper Lip

\[ F (2,15)=4.366, p=.032 \]

Upper Lip-Lower Lip

(Moss & Grigos, in preparation)
* = Main Effect of Group, p = .018
SUMMARY
&
DISCUSSION
Perceptual

Consonant and vowel errors greater in CAS than SD and TD.

Consonant and vowel errors increase as syllable length increases.

Error consistency is greater in TD and SD than CAS.
SUMMARY OF FINDINGS

**Kinematic**

Movement duration longer in CAS/SD than TD.

CAS more variable than SD and TD

Trend for amplitude to be large in SD in 3 syllable words.

Evidence that coordination is poorer in CAS than SD/TD

Variable word length effects
DISCUSSION

Broad group differences: CAS/SD vs. TD

- Longer duration may reflect adaptations to the motor plan
  - Means for increasing stability

Differences between impaired groups: CAS vs. SD

- Movement constraints in SD
- Movement constraints in CAS
MOVEMENT STABILITY IN CAS

Evidence of motor deficit?

STI in CAS = reduced ability to generate/execute stable motor plan

Degrees of Freedom problem
- Greater variability in CAS than SD
Do children with CAS have a coordination impairment?

Children with CAS:

- Do not differ in degree of spatial-temporal coupling when productions are accurate.
- Do differ in the variability of how coupling is achieved each time.

We predict that as speaking tasks become more complex, spatial coupling will decrease, temporal synchrony will increase, and variability will increase. Production errors may occur for these reasons.
NEWELL’S CONSTRAINT MODEL
(NEWELL, 1986)

Speech motor deficits

Task Constraints

Environmental Constraints
MOVING AHEAD....

- Error analyses
- Longitudinal research tracking development of articulatory control in children with early diagnosis of speech delay