Evidence-based update on ultrasound biofeedback for treating speech sound errors

Dr. Jonathan Preston, CCC-SLP

Research Scientist, Haskins Laboratories &
Assistant Professor, Communication Disorders Dept,
Southern Connecticut State University

Haskins Laboratories

Southern Connecticut State University SCSU

Acknowledgement

- Support for this research provided by:
  - the Childhood Apraxia of Speech Association of North America (CASANA)
  - Connecticut State University/AAUP grant
  - NIH grant 1R03DC013152-01A1

2

Outline

- Review the current evidence base behind the use of ultrasound biofeedback, including some of my research on the topic
  - Acquired apraxia of speech
  - Childhood apraxia of speech
  - Residual speech sound errors

3

Ultrasound biofeedback training

- **Biofeedback**: "The use of instrumentation to make covert physiological processes more overt; it also includes electronic options for shaping appropriate responses" (Huang, Wolf & He, 2006)
- Other biofeedback applications in speech therapy:
  - Electropalatography
  - Acoustic biofeedback: Spectrograms/LPC spectra
  - Nasal endoscopy

4

Why ultrasound?

- Makes implicit movements of the tongue more explicit
- Real-time images allow clinicians to provide more precise cues and allow the child to self-monitor
- Auditory perception may be weak in individuals with speech sound errors (e.g., Shuster, 1998; Rvachew et al., 2003)
  - Focus more on whether the client can "see" the desired articulation rather than "hear" it

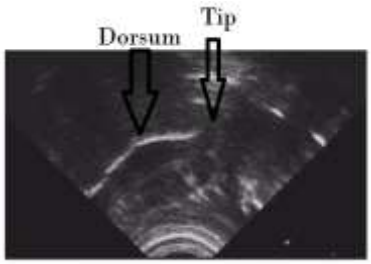
5

Why ultrasound?

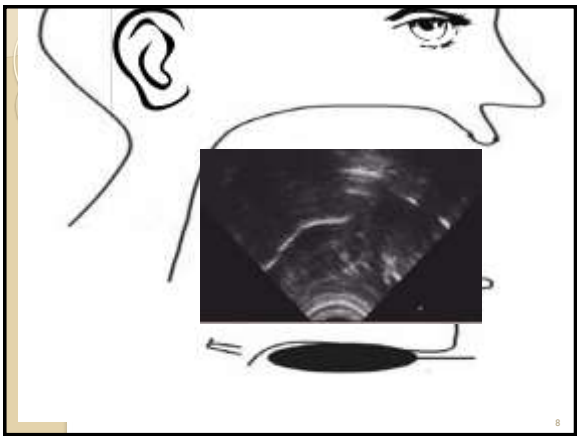
- Shows order between objects of different densities
  - Uses sound waves, acoustic energy
- No known or reported side effects

6

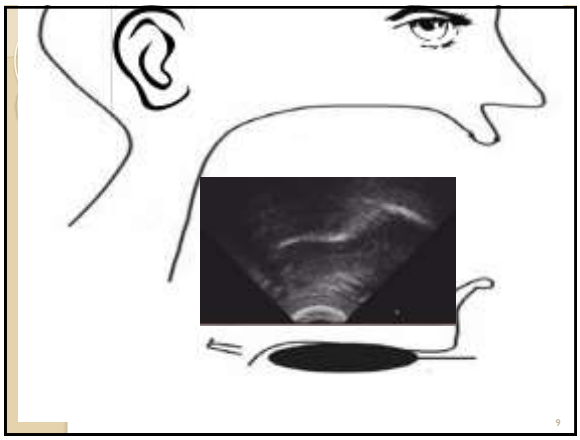
Sagittal view of /r/



7

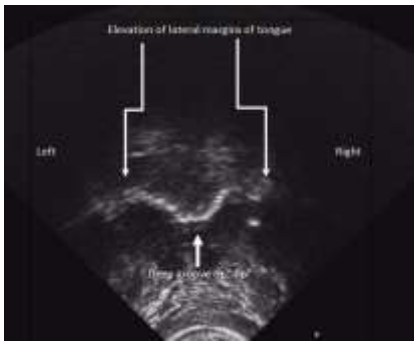


8



9

Coronal view of /r/



10

De-mystifying ultrasound

- Demonstration

11

Video examples of /r/

- U005 /ar, or/

12

Information available with ultrasound

- Only the tongue
  - Shape, movement patterning
- Sagittal (front-to-back) view is most common
  - Visualize tongue tip, blade, dorsum, root
- Also can use coronal (left-to-right) view
  - Visualize lateral margins of tongue

13

Motor Learning Theory

- Ultrasound biofeedback provides
  - Knowledge of Performance
    - Information about the nature of the movement
  - External focus of attention
    - Freedman et al. (2007)
- Some other important elements that facilitate motor learning include:
  - Practice variability
  - Complexity of target
  - Reduced feedback
    - cf. Maas et al (2008); Schmidt & Lee (2011)

14

History of Ultrasound in Speech-Language Pathology

- Many studies analyzing tongue motion in various language with ultrasound
  - Eg., Campbell et al. (2010); Stone et al. (2004)
- What about using the technology for people with speech disorders?
- Video example U002 self-cueing

15

Levels of Evidence (Robey, 2004)

- Phases of treatment research
  - √ Phase I: Identify a therapeutic effect, estimate magnitude. Usually small sample sizes (often case studies or small group)
  - √ Phase II: Refine protocol, expand population, study magnitude of effect.
  - Phase III: Randomized Controlled trials
  - Phase IV: Field research, clinical implementation
  - Phase V: Cost-benefit analyses (who benefits and at what cost)

16

Phase I evidence of ultrasound biofeedback: Case Studies

- 9 yr old with [w] for /r/ substitution
  - Shawker & Sonies (1985)

TABLE 1. The Percentages of Correctly Articulated /r/ Sounds in 20 Single Words and Open-Ended Sentences

	Single Words	Open-Ended Sentences
1. Pretreatment	88%	39%
2. During treatment	100%	100%
3. Immediately following treatment	100%	100%
4. 3 months following treatment	77%	80%

17

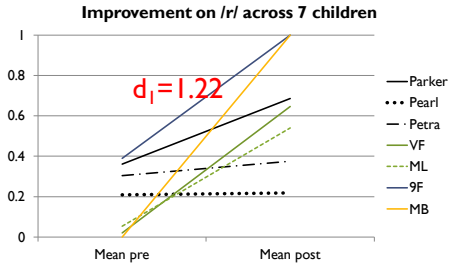
Phase I evidence of ultrasound biofeedback: Case Studies

- Deaf/hard of hearing: treating tense/lax vowel distinction & liquids /r, l/
  - Bacsfalvi (2010); Bacsfalvi & Bernhardt (2011); Bernhardt et al. (2003; 2005)
- Adolescents with normal hearing: Treating /r/
  - Adler-Bock et al. (2007); Modha et al., 2008
- Treating a frontal lisp
  - Lipetz & Bernhardt (2013)

18

Phase I evidence of ultrasound biofeedback: Case Studies

- Participants from
  - Adler-Bock et al (2006), Bacsfalvi (2010), Modha et al (2008), Shawker & Sonies (1985)



19

PHASE I RESEARCH: CASE STUDY OF AN ADULT WITH ACQUIRED APRAXIA OF SPEECH

20

Case Study: Ultrasound Biofeedback for AOS

- Acquired apraxia of speech (AOS)
- 59 year old woman 14 months post-CVA (left MCA)
- Moderately intelligible, moderate-severe AOS with residual aphasia
- Four months unsuccessful treatment trying to elicit /r/

Preston & Leaman (in press)

21

Case Study: Ultrasound Biofeedback for AOS

- Research Design
  - Multiple baseline single subject design
    - Treated:
      - Initial /r/ for 6 sessions,
      - Final /r/ for 6 sessions
    - Untreated:
      - Voiced plosives

22

Case Study: Ultrasound Biofeedback for AOS

- Treatment protocol:
  - Administer probes to track progress
  - 10 mins of pre-practice with ultrasound
  - 10 mins of practice with ultrasound
  - 10 mins of practice NO ultrasound
  - 10 mins of practice with ultrasound
  - 10 mins of practice NO ultrasound

Preston & Leaman (in press)

23

Treatment Protocol: Practice blocks

- Four levels of complexity
  - Syllable
  - Monosyllabic word
  - Multisyllabic word
  - Phrases
- Step up to next level if 5/6 correct in a block
- Step down to previous level of 0/6 correct in a block
- Stay if 1-4 correct in a block of 6

Preston & Leaman (in press)

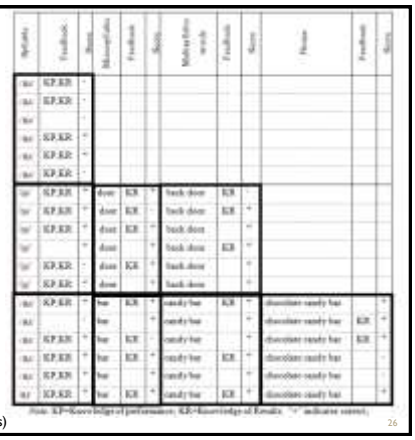
24

Case Study: Ultrasound Biofeedback for AOS

- During /r/, she was lacking pharyngeal constriction, elevation of tongue blade
- Therapy goal: Improve production of initial and final /r/
- Six sessions practicing initial /r/ in /re, ro/ followed by six sessions practicing final /r/ in /ɑr,ɔr/

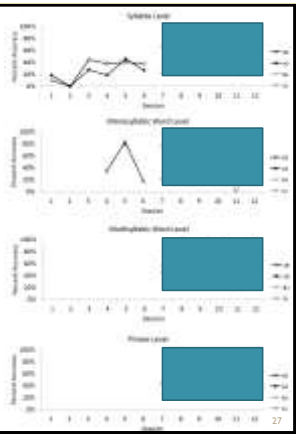
Preston & Leaman (in press) 25

Treatment Protocol: Practice blocks



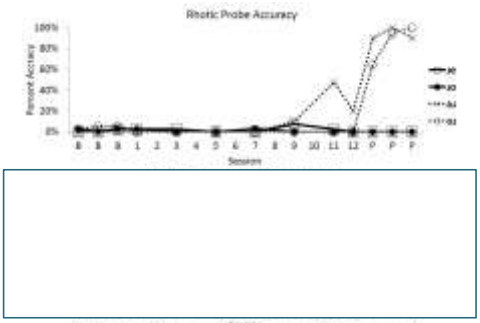
Preston & Leaman (in press) 26

Results: Within session performance



Preston & Leaman (in press) 27

Results: Motor Learning Probes



Preston & Leaman (in press) 28

Implications

- Ultrasound visual feedback might be a useful tool for treating speech errors in adults with acquired AOS
- Evidence of delay before motor learning
- This is the only study of ultrasound and AOS, so let's be prudent

Preston & Leaman (in press) 29

RECENT PHASE II RESEARCH WITH CHILDHOOD APRAXIA OF SPEECH

30

Characteristics of persisting CAS

- Children whose speech errors persist past the age of ~9 years
- No two children with CAS sound alike
- Not "just an /r, l, s/ problem"
  - But often includes an /r, l, s/ problem

31

Characteristics of persisting CAS

- Typically involve errors on "late-8" sounds /r, l, s, z, ʃ, ʒ, θ, ð/ If the child has a history of CAS, we may see
  - Occasional vowel errors
  - Sequencing errors (e.g., clusters)
  - More errors on multisyllabic words
  - Prosodic difficulties: Excess/equal stress, Monopitch/monoloudness, Slower rate

32

Implications?

- We may need to teach new motor plan (e.g., tongue configuration) but should also consider how this interacts with *movement*

33

Ultrasound biofeedback training

- Ultrasound may be a useful biofeedback tool for correcting certain errors on lingual phonemes
  - Liquids /r, l/
  - Lateralized sibilants
  - Velar-alveolar contrasts
  - Vowels
- May be particularly useful for sound sequences (e.g., clusters)

34

Our Research Protocol

- Select sound patterns (CV, VC, CC)
- First, achieve stimulability
- Then work on isolation, monosyllabic words, multisyllabic words, phrases, sentences (all in a single session, if possible)
- Establish a motor plan for a sound sequence, then generalize this to various words and prosodic contexts

Preston, Brick & Landi (in press)

35

Our Research Protocol

- To achieve stimulability, use
  - Model of clinician's tongue shape
  - Visual "targets" on the screen
  - Shaping
    - /l/ → [ɜˠ] (cf. Shriberg, 1975)
    - /a/ → [ɜˠ] (cf. Secord et a., 2007)

Preston, Brick & Landi (in press)

36

Our Research Protocol

- Think of how a motor plan for /r/ fits into the context of "real" speech
  - Once a static posture is achieved, we want to help the child recognize the parameters than CAN and CANNOT be varied
  - Target movements, not just static postures
  - practice production under varied respiratory/phonotory/aerodynamic demands

Preston, Brick & Landi (in press)

37

Our Research Protocol

- Use principles designed to facilitate motor learning
- Practice the target with:
  - Varied rate (fast-slow)
  - Varied loudness (loud-soft)
  - Varied intonation (rising-falling)
    - (cf. Dynamic Temporal and Tactile Cueing, Strand et al. 2006)

Preston, Brick & Landi (in press)

38

Video Example

- U002 vary rate and intonation

39

Research Design

- Multiple baseline across behaviors single subject design
- Assess accuracy of 8 potential treatment targets using probes (word imitation)
- 18 Treatment Sessions
  - 60 minute sessions, twice per week.
    - 30 mins using ultrasound
    - 15 mins "traditional" therapy (artic, PML)
    - 10 minutes data collection
- 3 post-treatment sessions

Preston, Brick & Landi (in press)

40

Research Design

- Work on up to 2 treatment targets per session while collecting data on untreated patterns
- Discontinue after reaching 80% accuracy two sessions in a row (as judged by 2 listeners)

Preston, Brick & Landi (in press)

41

Research Participants

- 6 children with CAS
  - <85% on Sequencing or Focal Oral Motor subtests of VMPAC
  - Errors on DDK, vowels, consonant sequences, multisyllabic word productions
  - Errors on lingual sounds
- Normal receptive language and nonverbal IQ
- Ages 9-15

Preston, Brick & Landi (in press)

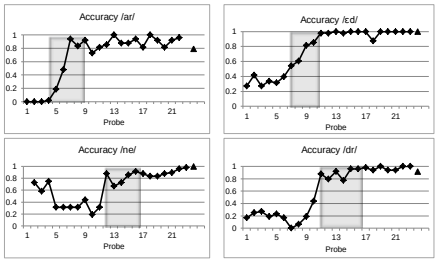
42

Video Examples

- U012 /ne/

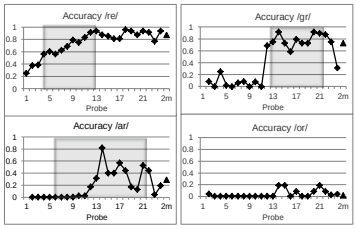
Preston, Brick & Landi (in press) 43

Example Results: 12 yr old with CAS



Preston, Brick & Landi (in press) 44

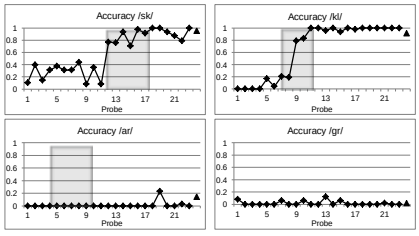
Example Results: 10 yr old with CAS



Preston, Brick & Landi (in press) 45

Audio example: /gr/ 10 yr old CAS

Preston, Brick & Landi (in press) 46



Preston, Brick & Landi (in press) 47

Audio example: /sk/ 13 yr old CAS

Pre-treatment

Post- treatment

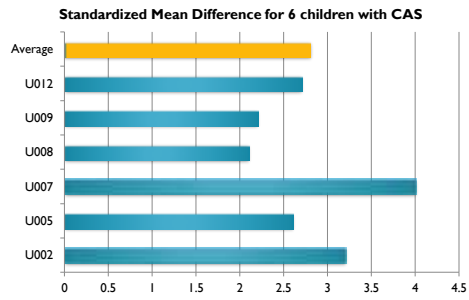
Preston, Brick & Landi (in press) 48

Video: /kl/ clusters

Preston, Brick & Landi (in press)

49

Effect Sizes



Preston, Brick & Landi (in press)

50

CAS participants

- Average number of sessions to reach 80% accuracy: 5
- Average increase in accuracy of treated targets: 53%

Preston, Brick & Landi (in press)

51

Summary

- Can train specific sound or sound sequences
- Results show that ultrasound biofeedback is better than NO treatment on a sound pattern
- This research design doesn't tell us that this intervention is superior to any other treatment
  - Need for direct comparison between treatment approaches
- Does the prosodic cueing help with learning?

52

PHASE II RESEARCH ON ULTRASOUND BIOFEEDBACK FOR RESIDUAL SPEECH SOUND ERRORS

53

Application of ultrasound to residual speech sound disorders

- Not all children with residual speech sound errors have CAS
- Some children with speech sound errors do not respond well to traditional "artic therapy"
- Need to determine if children with persisting speech sound errors can show improvements with ultrasound biofeedback
- Need to develop replicable protocols for implementing ultrasound biofeedback

Preston et al., in prep

54

Treatment procedures

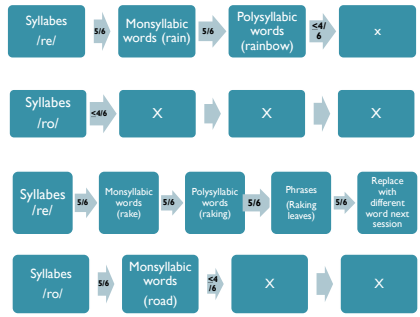
- Select target (sound, position in syllable), then select corresponding monosyllabic words, multisyllabic words, phases

Target	Variants	Monosyl.	Multisyllabic	Phrase
Initial /r/	/re/	Rake	Raking	raking the leaves
	/ro/	road	rodeo	rodeos with cowboys
Initial /s/	/si/			
	/so/			

Preston et al., in prep

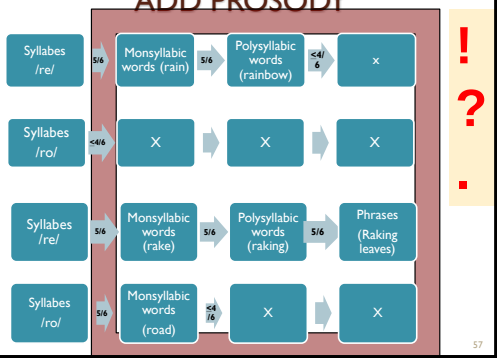
55

Treatment Procedures



56

Treatment Procedures: ADD PROSODY

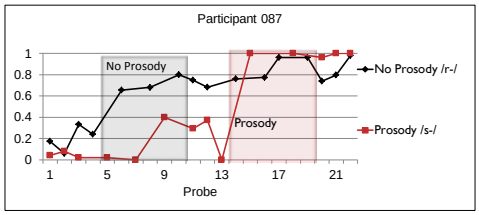


57

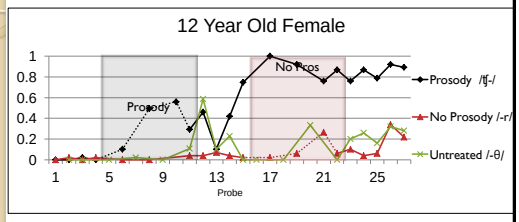
Examples of Prosodic cues

- 087 ro words and phrases
- 085 ar syllables-words with prosody

58



Preston et al., in prep



Preston et al., in prep

60

Advantages of Ultrasound Biofeedback

- Less guessing about articulation
- More information for the clinician and the client. E.g.,
  - Tongue grooving for /s/
  - For /r/, elevation of the lateral margins of the tongue, or elevation of the tongue dorsum and/or blade, and tongue root retraction

61

Advantages of Ultrasound Biofeedback

- ***Cues can be specific***. Clinicians can cue specific movements of different aspects of the tongue (e.g., dorsum, blade, lateral margins). It can become apparent to the clinician and the client if the target tongue position is being achieved.
- ***Children can understand what is expected and learn to self-cue***. Children can now see if they are achieving a particular target in a movement sequence.

62

Disadvantages of Ultrasound Biofeedback

- ***Cost/Access***
  - The system we use costs $5,500, plus the cost of a laptop. More expensive devices are on the market.
- ***Training***.
  - Equipment
  - Articulatory phonetics
- ***Child characteristics***
  - The approach is drill-oriented and required sustained attention
  - "Ideal" candidates have normal vision, good strong cognitive skills.
  - Children below about 7 years may not be good candidates

63

Disadvantages of Ultrasound Biofeedback

- ***Not a magic pill.***
  - Drill and repetition are still required.
  - Images are *only* of the tongue (cannot see palate)
  - To visualize the target position, speech is *slowed down*.
  - Approach is most valuable for establishing correct productions and achieving consistent productions at the syllable- and word-levels.
- ***More research is needed***.
  - Currently only Phase I & Phase II studies
  - More research & training are needed before widespread clinical implementation is likely

64

Ongoing/future work

- **Presently**
  - Comparing prosodic cues vs. no prosidic cues to see if this type of practice variability enhances motor learning in two cohorts of children:
    - Children with speech sound disorders with CAS
    - Children with speech sound disorders without CAS
- **Planned**
  - Phase II studies: Comparing gains with ultrasound biofeedback vs without ultrasound biofeedback
- **Future…**
  - Phase III studies (randomized control trials)?!

65

Summary

- In addition to achieving the target articulatory gesture, practice variability might be achieved through prosodic manipulation
- Ultrasound biofeedback might be an approach that is on the horizon for some cases of persisting speech sound disorders, including childhood apraxia of speech,
  - Consider it a tool in the toolbox of speech therapy

66

Summary: Ultrasound Biofeedback

- Phase I research (case studies)
  - Several
    - Now including an adult with AOS
- Phase II research (experimental control)
  - 1 study of childhood apraxia of speech
  - We're working on some more
- Phase III research (randomized trials)
  - Hopefully coming soon

67

Questions? Comments?

68

References

- Adler-Bock, M., Bernhardt, B., Gick, B., & Bacsfalvi, P. (2007). The Use of Ultrasound in Remediation of North American English /r/ in 2 Adolescents. *American Journal of Speech-Language Pathology, 16(2), 128-139.*
- Bernhardt, B., Bacsfalvi, P., Adler-Bock, M., Shimizu, R., Cheney, A., Giesbrecht, N., et al. (2008). Ultrasound as visual feedback in speech habilitation: Exploring consultative use in rural British Columbia, Canada. *Clinical Linguistics & Phonetics, 22(2), 149 - 162.*
- Bernhardt, B., Gick, B., Bacsfalvi, P., & Adler-Bock, M. (2005). Ultrasound in speech therapy with adolescents and adults. *Clinical Linguistics & Phonetics, 19(6/7), 605-617.*
- Bernhardt, B., Gick, B., Bacsfalvi, P., & Ashdown, J. (2003). Speech habilitation of hard of hearing adolescents using electropalatography and ultrasound as evaluated by trained listeners. *Clinical Linguistics & Phonetics, 17(3), 199 - 216.*
- Modha, G., Bernhardt, B., Church, R., & Bacsfalvi, P. (2008). Ultrasound in treatment of /r/: A case study. *Intl. Jnl. of Lang. & Communication Disorders, 43 (3), 43(3), 323-329.*
- Preston, J.L. & Leaman, M. (in press). Ultrasound visual feedback for acquired apraxia of speech: A case report. *Aphasiology.*
- Strand, E., Stoeckel, R., & Baas, B. (2006). Treatment of severe childhood apraxia of speech: A treatment efficacy study. *Journal of Medical Speech Language Pathology, 14(4), 297.*
- Shriberg, L. D. (1975). A response evocation program for /er/. *Journal of Speech & Hearing Disorders, 40(1), 92-105.*

69