INDIVIDUALIZED TARGETS FOR ACOUSTIC BIOFEEDBACK TO TREAT RESIDUAL /r/ ERRORS

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INTRODUCTION

The English /r/ sound is a late-emerging, motorically challenging sound; residual errors affecting /r/ may persist into adolescence, even after years of traditional therapy.

Spectral acoustic biofeedback is a promising approach to treat persistent /r/ distortions.

- ✧ The English /r/ sound has a characteristically lower third formant frequency (F3) than vowels, which provides a robust target for speakers to match on visual display.
- ✧ Biofeedback using the Computerized Speech Lab (KayPentax, Model 4150B) is reported to be efficacious [1,2], but cost and training are barriers to widespread clinical uptake.
- ✧ Our lab is currently developing **staRt**, a free and open-source biofeedback app.

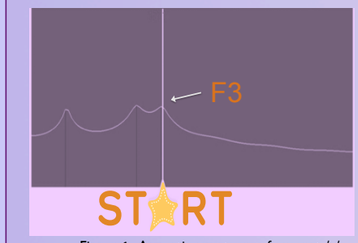


Figure 1: Acoustic spectrum of correct /r/ sound, with slider marking F3 target.

- ✧ **Aim**: Adapt our protocol to be user-friendly (usable without special training).
- ✧ **Barrier**: The optimal F3 target for /r/ varies by age/sex/height of child. Selecting the best target requires some trial/error and expertise.
- ✧ **Goal of this study: Develop an algorithm that will automatically predict an appropriate F3 target for /r/ based on measurements from non-rhotic vowel sounds.**

DERIVING FORMULA FOR PREDICTING F3 OF /r/

Background

1. Hagiwara [3] observed that F3 of /r/ typically falls within 60-80% of average F3 of adults' vowels (/i,æ,ɑ,u/).
2. In an ultrasound treatment study, Boyce et al. [4] observed that F3s of perceptually incorrect /r/ sounds fell above the 80% upper boundary, while the few perceptually correct tokens fell below this boundary.

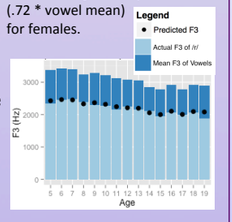
As 80% separates correct and incorrect /r/, we need to determine what point within 60-80% represents the best target for correct /r/.

Children with corrected /r/ following speech intervention have adequate number of correct and incorrect /r/ tokens to test 80% boundary and to find an appropriate target for /r/.

Formula Derivation

- ✧ Within 60-80% range, what scale factor (multiplier) brings us closest to the center of distribution of F3s of correct /r/ in a normative sample? [5]
- For each age/sex group, calculated average F3 of /æ,ɑ,u/ (/i/ eliminated as outlier).
- Beginning at .8, lowered scale factor in increments of .01 until reaching F3 closest to average F3 of /r/ for each age/sex group.

Figure 2: Normative F3s of /r/ and vowel averages with predicted F3 (.72 * vowel mean) for females.



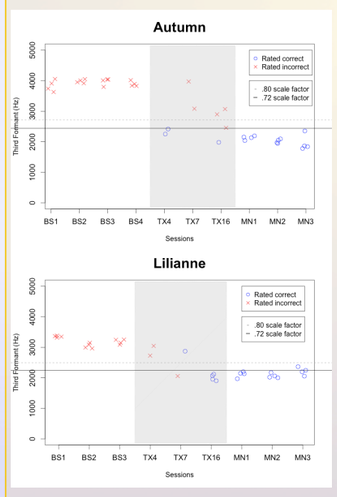
Process yielded scale factors of .72 for females and .68 for males

STUDY 1 – CHILDREN WITH REMEDIATED /r/

Q1: Do the predicted target values match actual F3 values observed in children whose /r/ misarticulation resolved during treatment?

- ✧ Selected two children with corrected vocalic /r/ from biofeedback intervention study. [6]
- ✧ Measured F3 of /r/ and vowels (/æ,ɑ,u/) from word probes elicited throughout study.
- ✧ Exploratory analysis: Applied .8 scale factor to compare observed F3s with Hagiwara/Boyce findings.

Figure 3: Correct/Incorrect actual F3s of /r/ with scale factor of .8 and .72



- Autumn: 20/21 incorrect tokens above cutoff & 15/15 correct tokens below cutoff.
- Lilianne: 14/15 incorrect tokens above cutoff & 16/17 correct tokens below cutoff.

- ✧ Findings strongly consistent with previous research suggesting that .8 separates correct and incorrect /r/.
- ✧ For our major question (Q1), applied revised scale factors.
- ✧ Finding: F3 targets calculated from normative data were higher than observed F3s.

- This difference was statistically significant for Autumn ($t(14) = -7.8$, $p < .001$) and approached significance for Lilianne ($t(16) = -1.83$, $p = 0.09$).
- Actual scale factors calculated to be .61 (Autumn) and .69 (Lilianne).

A1: *The scale factor derived from normative data for females is not low enough to predict the F3 of /r/ in children whose misarticulation resolved fully during treatment.*

STUDY 2 – TYPICALLY DEVELOPING CHILDREN

Q2: Why were F3 values predicted from our formula higher than actual F3 values observed in Study 1?

Possible explanations:

A. Task effect (single word elicitation in treatment study, phrases in normative study).	B. Children in remediated sample had learned hyperarticulated version of /r/.	C. The normative group average data were not representative of children in our sample.

We explored these possibilities with TD individuals (n=11, ages 9-15).

- ✧ Replicated phrase task used in normative study [5] and word task used in treatment study [6].
- ✧ For each task, predicted target F3 of /r/ from vowel average /æ,ɑ,u/.
- ✧ Compared predicted and actual F3 of /r/ for each child.

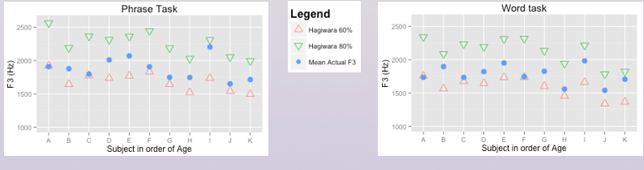
Figure 4: Predicted and actual mean F3 of /r/

- Predicted F3s were significantly **higher** than actual F3s, $t(10) = 3$, $p = 0.01$.
- Predicted F3s were significantly **higher** than actual F3s, $t(10) = 2.75$, $p = 0.02$.

A2: *Predicted F3s were significantly higher than actual F3s from TD children in both tasks. Supports account C: normative group average data not representative of children in our sample. May reflect dialect differences.*

Q3: Do actual mean F3s of /r/ in typically developing children fall within the broader 60-80% range?

Figure 5: 60-80% range and actual mean F3 of /r/



A3: *Most actual mean F3s (10/11) did fall within broader 60-80% range, near the lower end.*

CONCLUSIONS

Results from Studies 1-2 suggest that a lower scale factor would more accurately predict F3 of /r/ in both samples.

- ✧ Using Study 2 sample (TD), we calculated the scale factors needed to predict actual F3s of /r/ in both tasks.
  - Females: .68 phrases, .69 words
  - Males: .63 phrases, .63 words
- ✧ We are currently investigating whether the noted sex difference in scale factor is robust.

We will be using these further lowered scale factors as targets for app-based biofeedback intervention.

- ✧ The next goal is to implement automatized calculation of targets using these scale factors.
- ✧ To be incorporated into setup protocol of staRt biofeedback app.

Predicting an individual's F3 of /r/ from F3s of vowels contributes to an empirical understanding of /r/ acoustic properties and has direct clinical applications.

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