Visual-acoustic biofeedback for residual /r/ errors: Synthesis of research and implications for practice

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Disclosure

The authors are involved in the development of staRt, an app to provide visual-acoustic biofeedback treatment. They do not receive financial compensation for their role in developing the app.

Residual speech errors

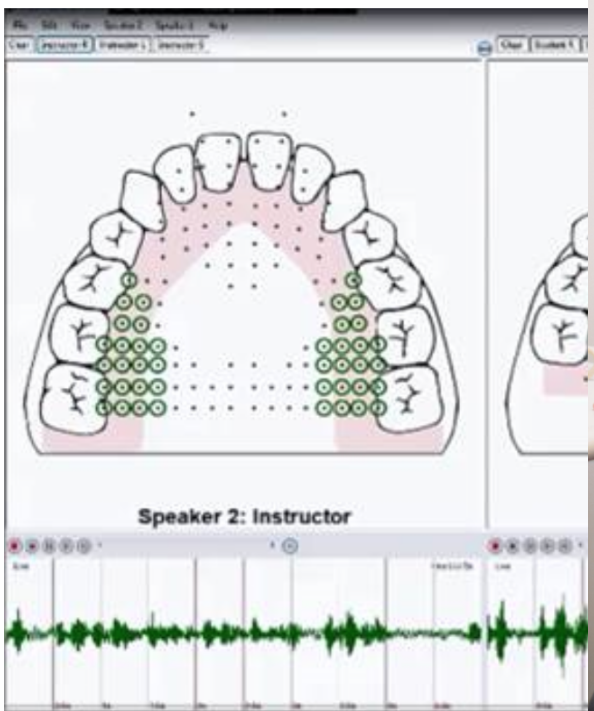
- Even highly unintelligible children generally converge on accurate speech by 8-9 years of age.
- Errors continuing past this point are classified as residual speech errors.
  - May persist through adolescence and, in 1-2% of speakers, into adulthood (Culton, 1986).
- Can have negative impact on academic, social, or psycho-emotional development (Hitchcock, Harel, & McAllister Byun, 2015).
- Focus of this research is on /r/, considered one of the most challenging sounds to treat.

What is biofeedback?

- Using instrumentation to create a real-time image of aspects of speech that are subtle or difficult to perceive under ordinary circumstances.
  - Making this information visible gives the client insight into his own output.
  - Goal is to bring unconscious processes under conscious control.

What is biofeedback?

- Various technologies can be used to provide different types of real-time information about speech.



Visual-acoustic biofeedback

- Real-time LPC spectrum shows resonant frequencies of vocal tract in real time.
- Clinician presents a visual template representing correct production of target sound.
- Speaker alters output in an effort to achieve a better match for the target.

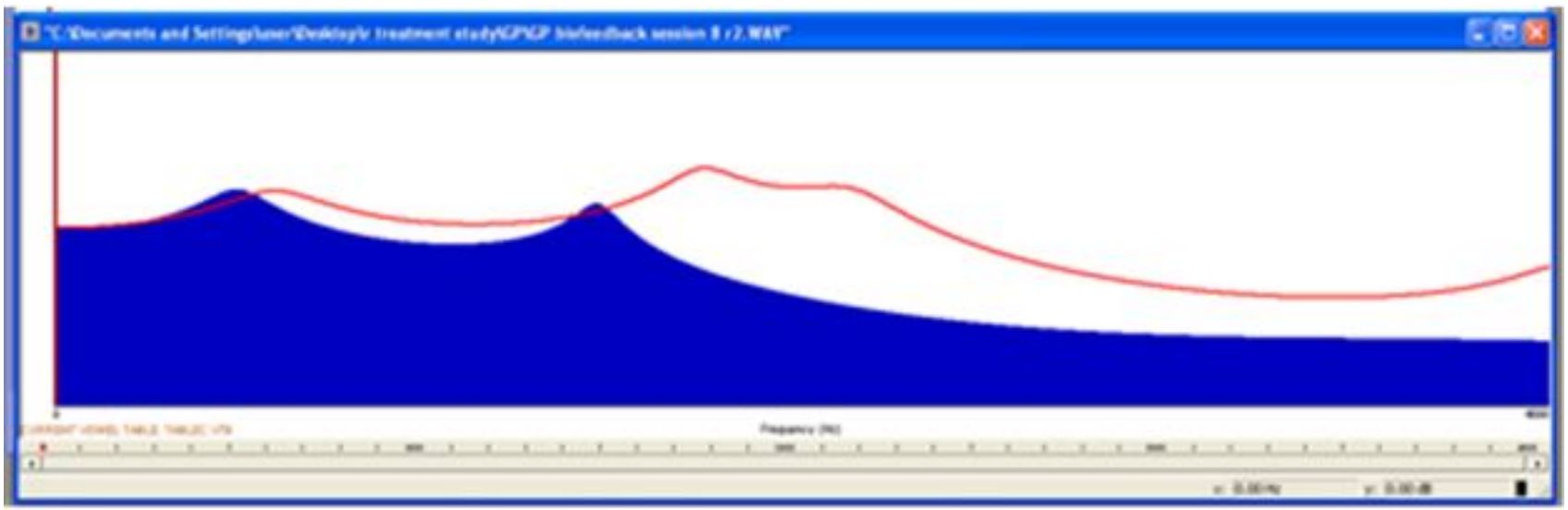


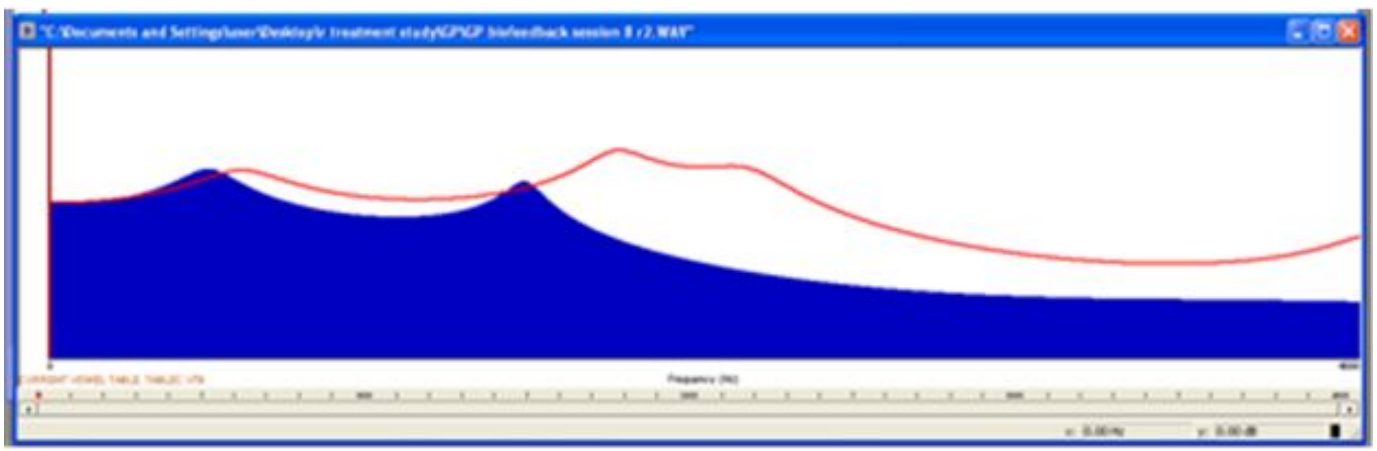
Figure 1: Visual acoustic biofeedback display

Visual-acoustic biofeedback intervention

- Videos in this talk feature staRt, an app for visual-acoustic biofeedback that is in development at NYU.
- However, actual treatment in the studies described here used CSL Sona-Match (KayPentax).

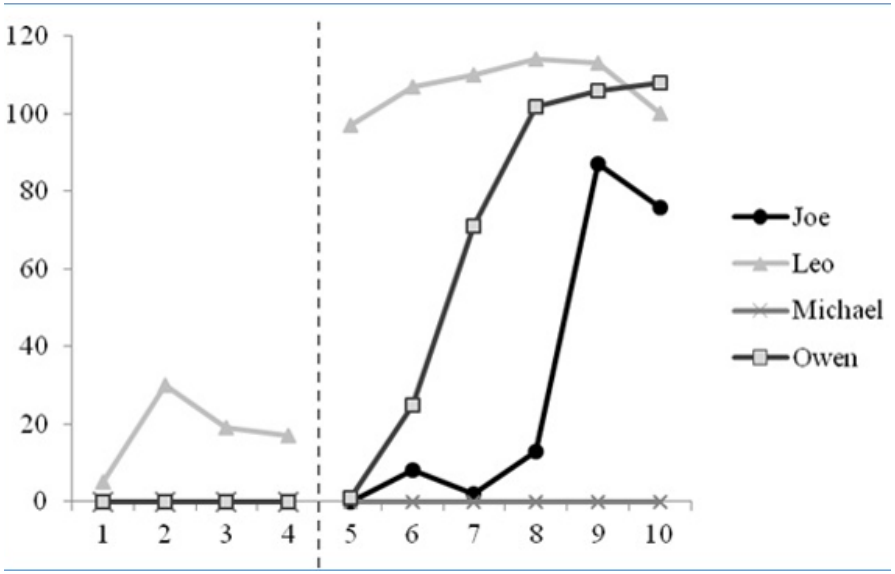
Why use biofeedback?

- May be helpful for speakers who have difficulty making an auditory judgment of the accuracy of their own output
- Principles of motor learning (e.g., Maas et al., 2008):
  - Provides a detailed form of knowledge of performance (KP) feedback. Predicted to be most useful in early stages of learning.
  - May encourage an external direction of attentional focus.



Why use biofeedback?

- Evidence base for the efficacy of visual-acoustic biofeedback is small but growing.
- Case studies (Shuster et al., 1992, 1995)
- Single-subject studies (McAllister Byun & Hitchcock 2012, McAllister Byun et al. 2016)
- Limitation: No well-controlled comparisons of traditional articulatory treatment versus biofeedback treatment.
- Generalization is a known challenge: Most respond in treatment setting, but not all carry gains away with them.



Goals of this research

- Previous research has not provided a well-controlled comparison of traditional articulatory versus biofeedback treatment for residual /r/ errors.
- We will present the results of two studies that specifically addressed this goal.
  - A single-subject randomization study: Sessions randomly alternated between biofeedback and traditional treatment (McAllister Byun, in press)
  - A study featuring a block of biofeedback treatment and a block of traditional treatment, counterbalanced in order across subjects (McAllister Byun & Campbell, 2016)

Studies I and II: Shared elements

Participants

- Native speakers of a rhotic dialect of English
- Misarticulated /r/ in >30% items on standard word probe
- Passed hearing and oral mechanism screening
- Exhibited no major speech-language deficits apart from /r/ misarticulation (some presented with additional residual speech errors)

Study I

- 5 males, 2 females
- 9;0-15;0 years (mean=12;3, sd=28.5 months)
- Duration of previous treatment ranged from 0-11 years (mean=3.7, sd=3.8)

Study II

- 7 males, 4 females
- 9;3-15;10 years (mean=11;3, sd=25 months)
- Duration of previous treatment ranged from .5-4.5 years (mean=2.3, sd=1.5)

Probe measures

- Assess generalization gains with list of untreated words containing /r/ in various phonetic contexts
- Measured both short-term and long-term generalization
  - 25-word probes administered at the start and end of each session
  - Longer-term generalization: 50-word probes administered in pre-treatment baseline and post-treatment maintenance phases, and between treatment phases in study 2

Treatment protocol

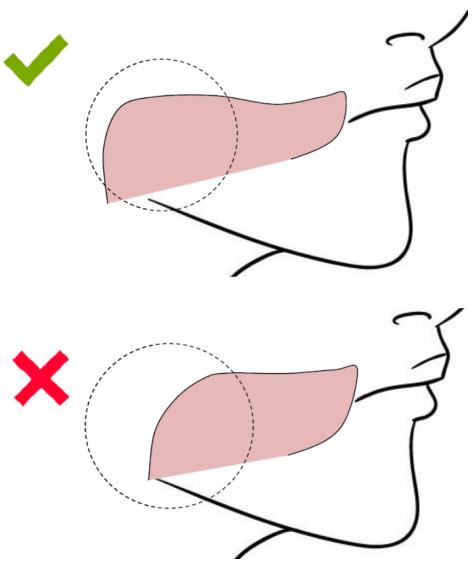
- Target words featured only vocalic rhotics (syllabic /r/ or postvocalic as in *care, fear*)
- Sessions were assigned to one of two treatment types:
  - Traditional (TRAD): Clinician provided auditory models and articulator placement cues.
  - Biofeedback (BF): Clinician encouraged client to match a target on real-time LPC display. No articulatory cues provided.

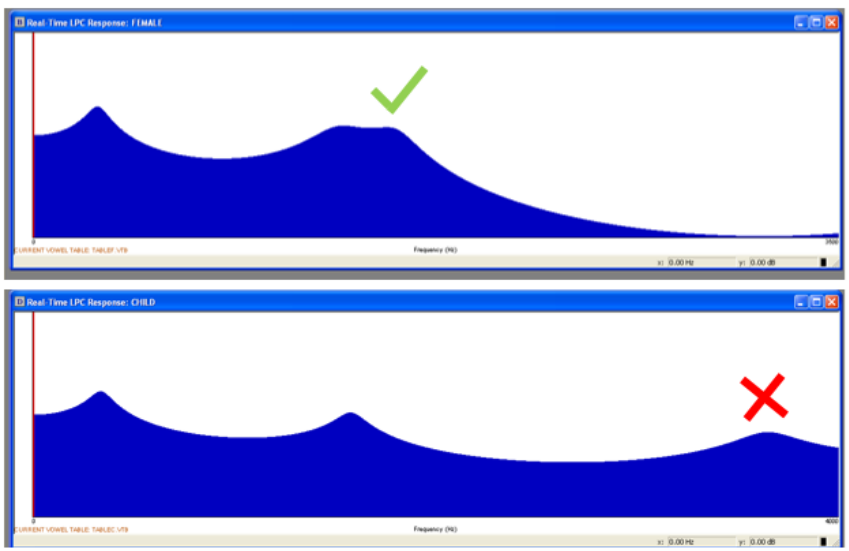
Treatment protocol

- Each session started with five minutes of free play.

Treatment protocol

- The first two sessions of each type featured extended instructions.
  - About articulator placement for /r/ (TRAD condition)
  - About the acoustic signature of correct /r/ and how to manipulate the LPC wave (BF condition)





Treatment protocol

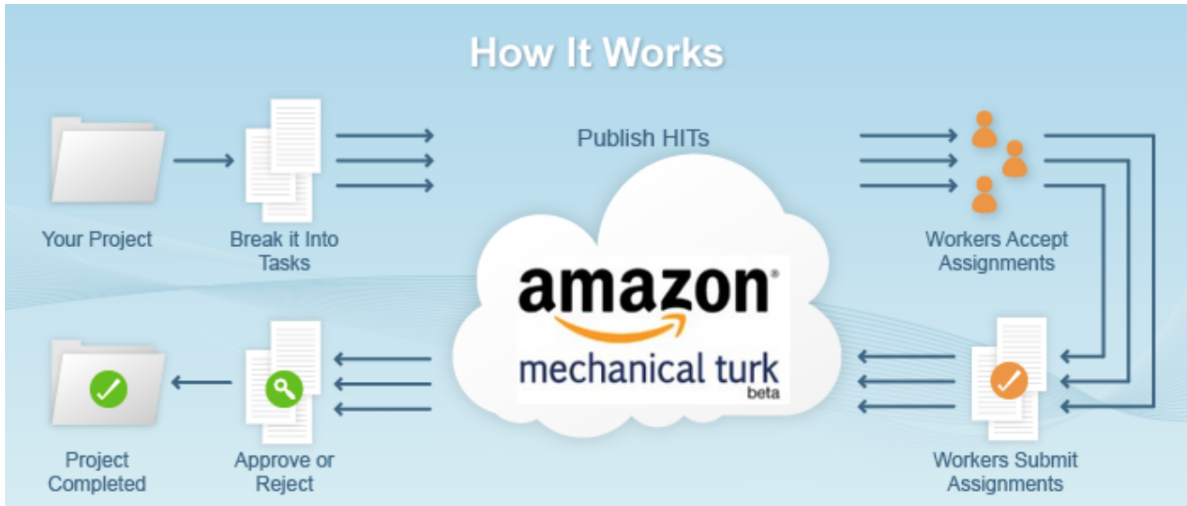
- 60 trials of words containing /r/ were elicited in blocks of 5.
- Clinician provided a focusing cue before each block and summary feedback after.

Adaptive difficulty using Challenge-/r/

- Use a challenge point framework (Guadagnoli & Lee, 2004; Rvachew & Brosseau-Lapre, 2012) to keep child at a level of difficulty expected to maximize learning.
- May be particularly important as a way to avoid excessive dependence on biofeedback.
- After 10 trials, Challenge-/r/ program (McAllister Byun, Hitchcock, & Ortiz, 2013) tallies accuracy:
  - If >80%, increase one difficulty parameter
  - If <50%, reduce one difficulty parameter
- Parameters adjusted: Feedback frequency, clinician model, word shape complexity.

Measurement and analysis

- All words elicited in BL, MN, and within-tx probes were rated by naive listeners recruited online (Amazon Mechanical Turk); each token rated by at least 9 unique listeners
- Binary correct/incorrect classification
- Percentage of “correct" votes out of total number of votes



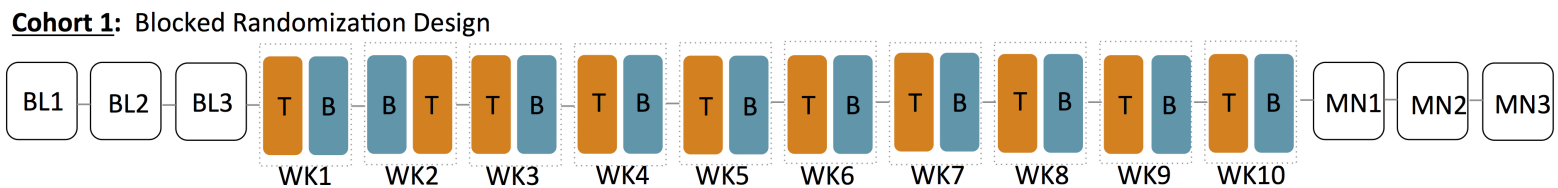
Studies I and II: Differences

Major difference: Design of study

- Study I used a single-subject randomization design.
- Study II sessions were blocked by treatment type, with order counterbalanced across groups.
- Recall that both studies allowed for both short-term and long-term evaluation of effects of treatment.

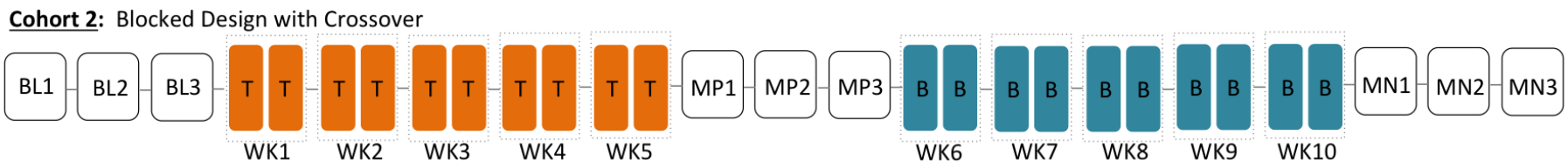
Study I design

- In a randomization design, sessions are randomly assigned to treatment conditions (e.g., Rvachew, 1988).
  - If there is a long-term learning trend, scores in both types of session will tend to go up over time.
  - However, increments of progress associated with the more effective treatment condition should be greater than with less effective condition.
- Can assess statistical significance of difference between conditions using randomization tests.
- Hypothesis: Randomization tests should indicate greater progress in biofeedback than traditional treatment sessions.



Study II design

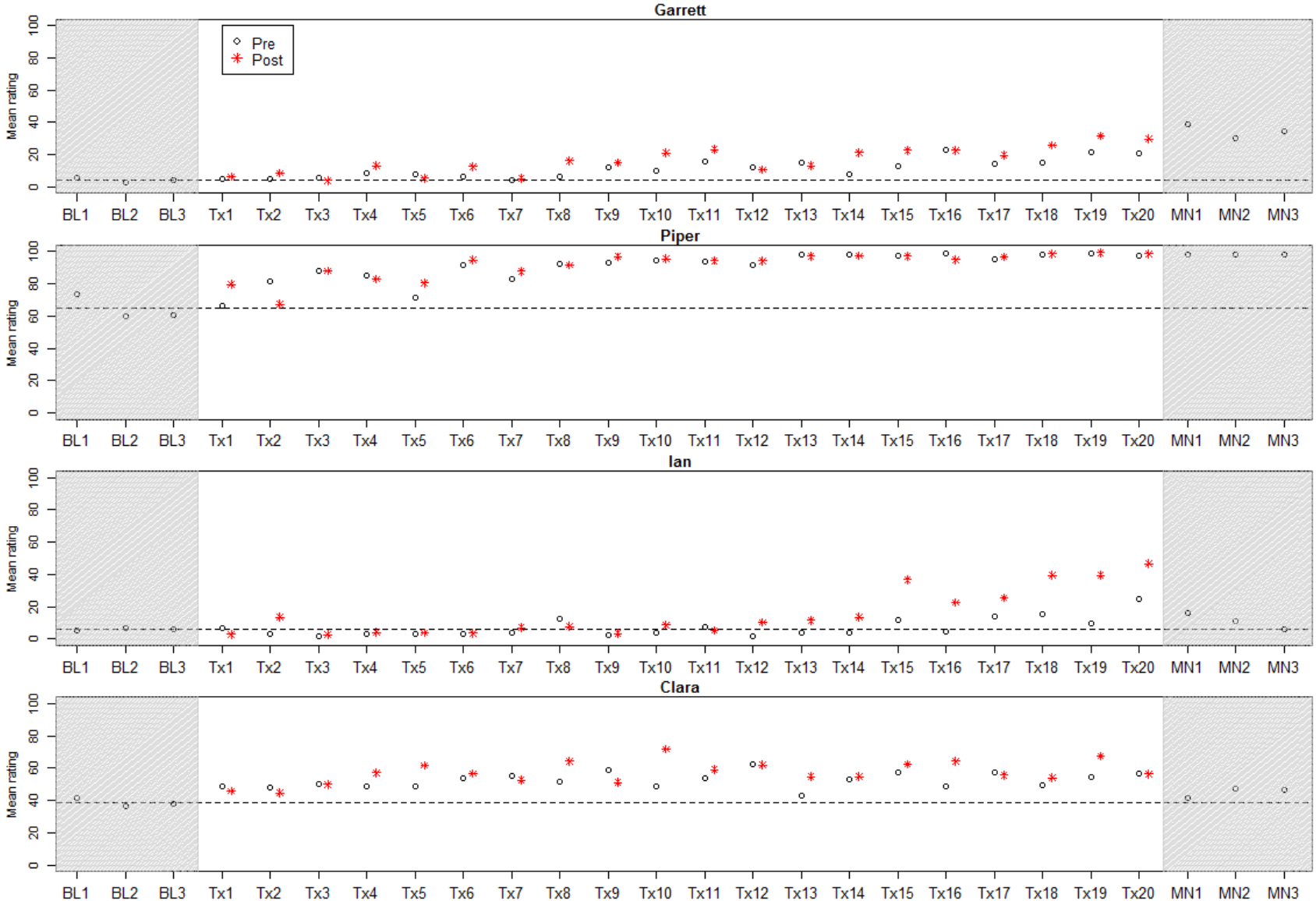
- Blocked treatment allows effect of a given treatment type to build up before switching.
- Can pool results across participants and look for a difference between treatment types in a regression model.
- Hypothesis: Phases of biofeedback treatment should be associated with significantly larger gains than phases of traditional treatment.



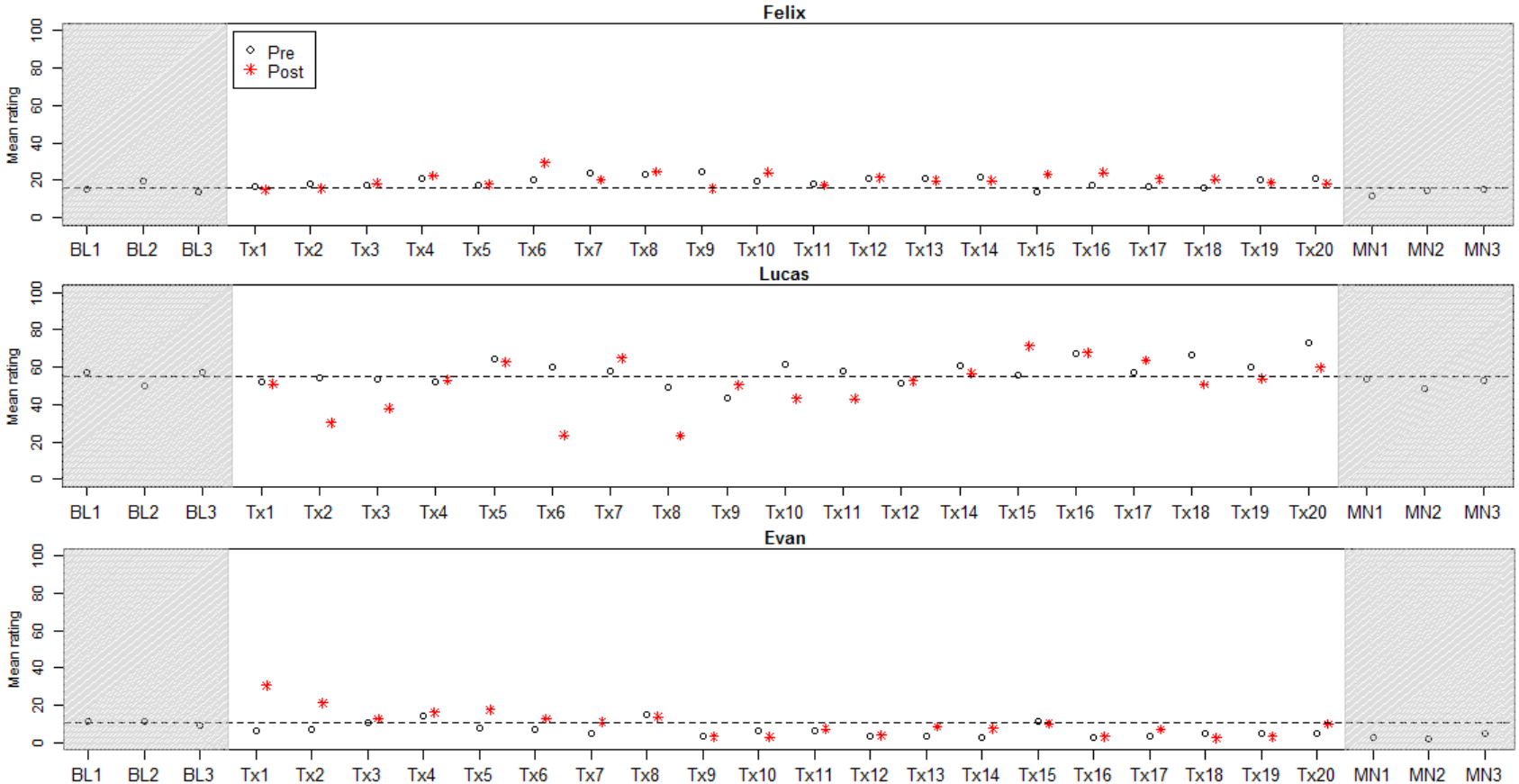
Study I: Visual inspection

- Results plotted here do not differentiate the effects of biofeedback versus traditional treatment; looking at combined treatment effect.
- All participants maintained an adequately stable baseline
- Mean effect size of 1.79, indicating positive change on average
- 2 strong responders, 2 moderate responders, 3 non-responders

Study I: Responders



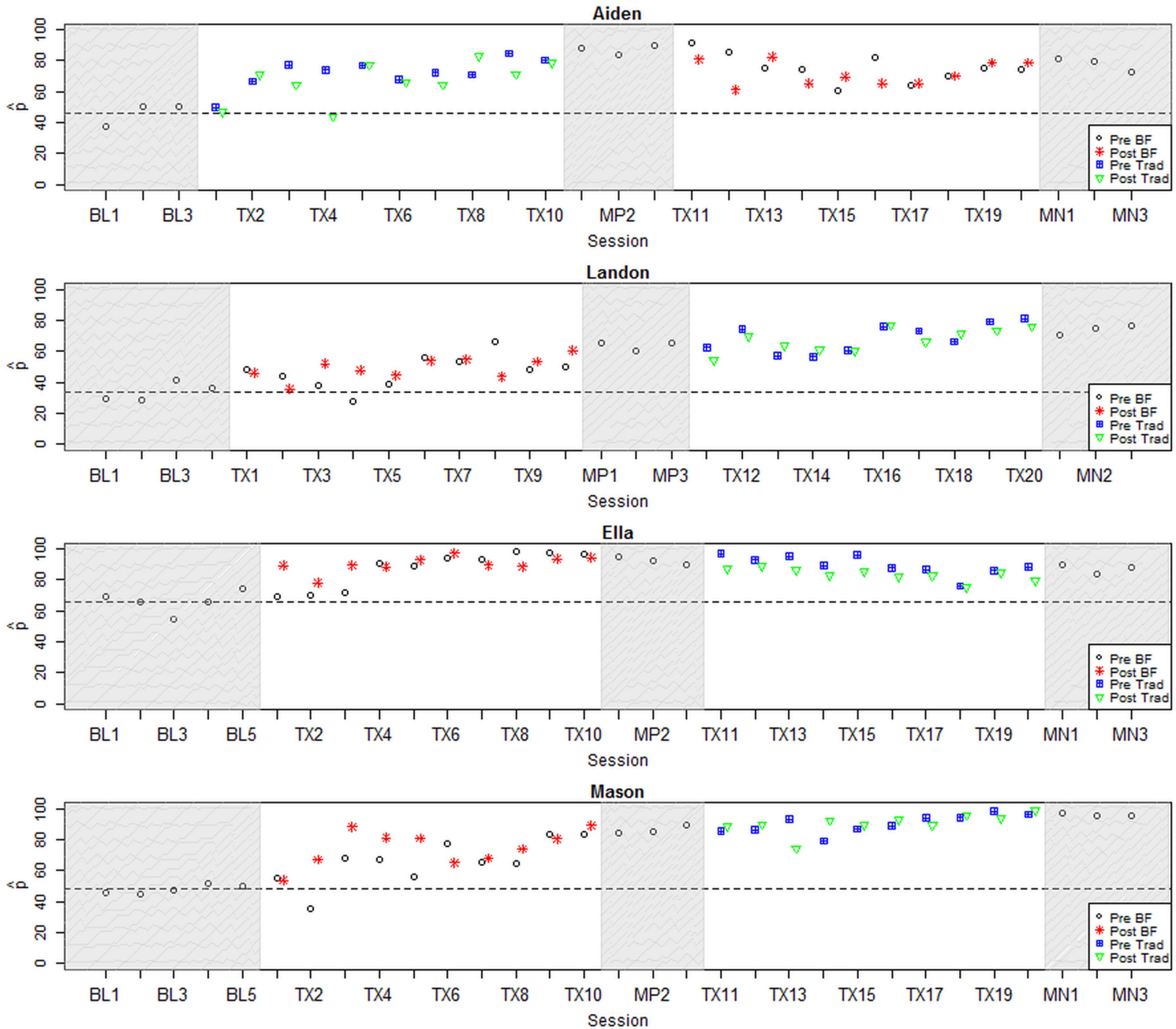
Study I: Nonresponders



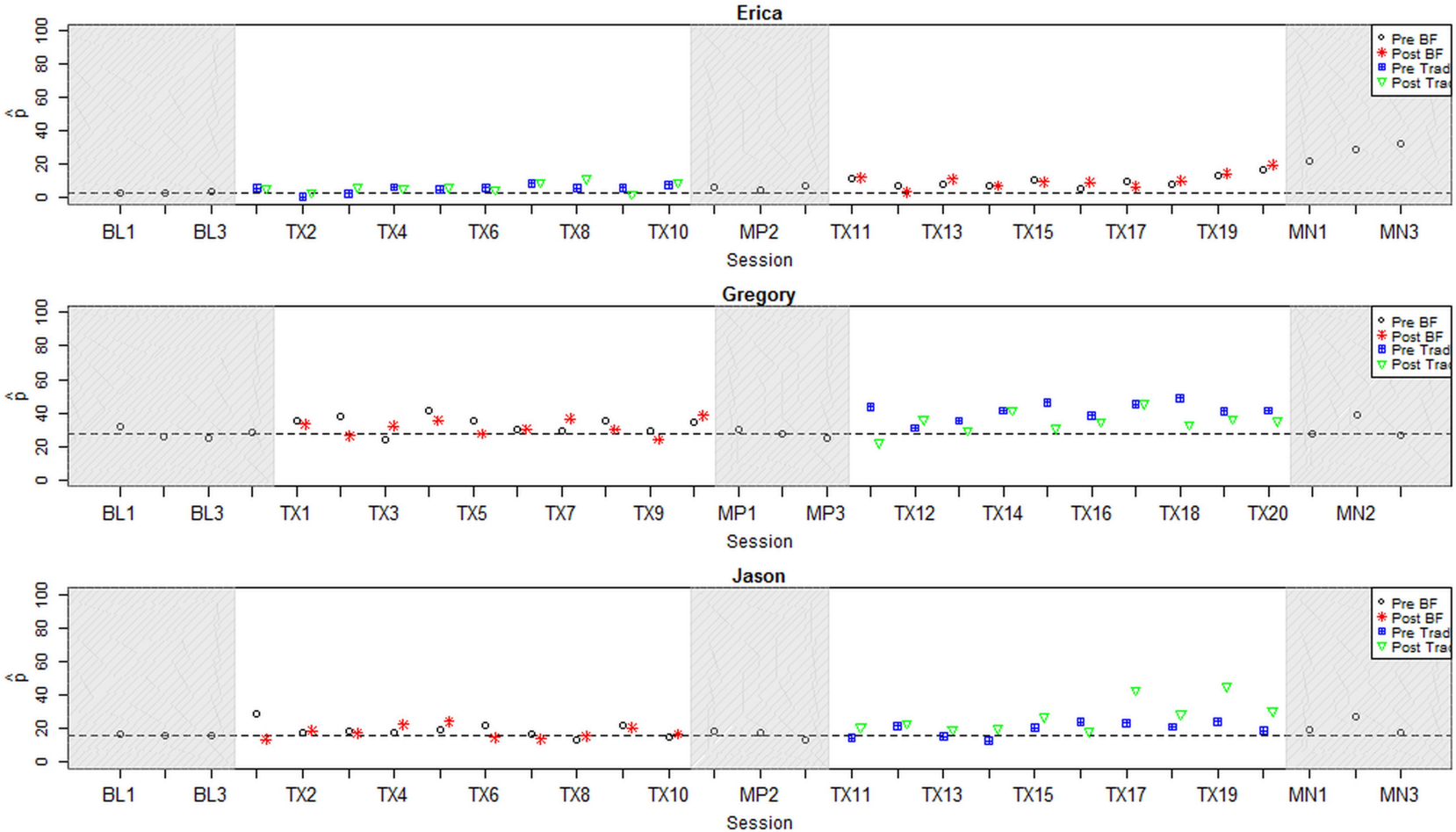
Study II

- All participants maintained an adequately stable baseline
- Mean effect size of 4.38, indicating positive change on average
- 4 strong responders, 3 moderate responders, 4 non-responders

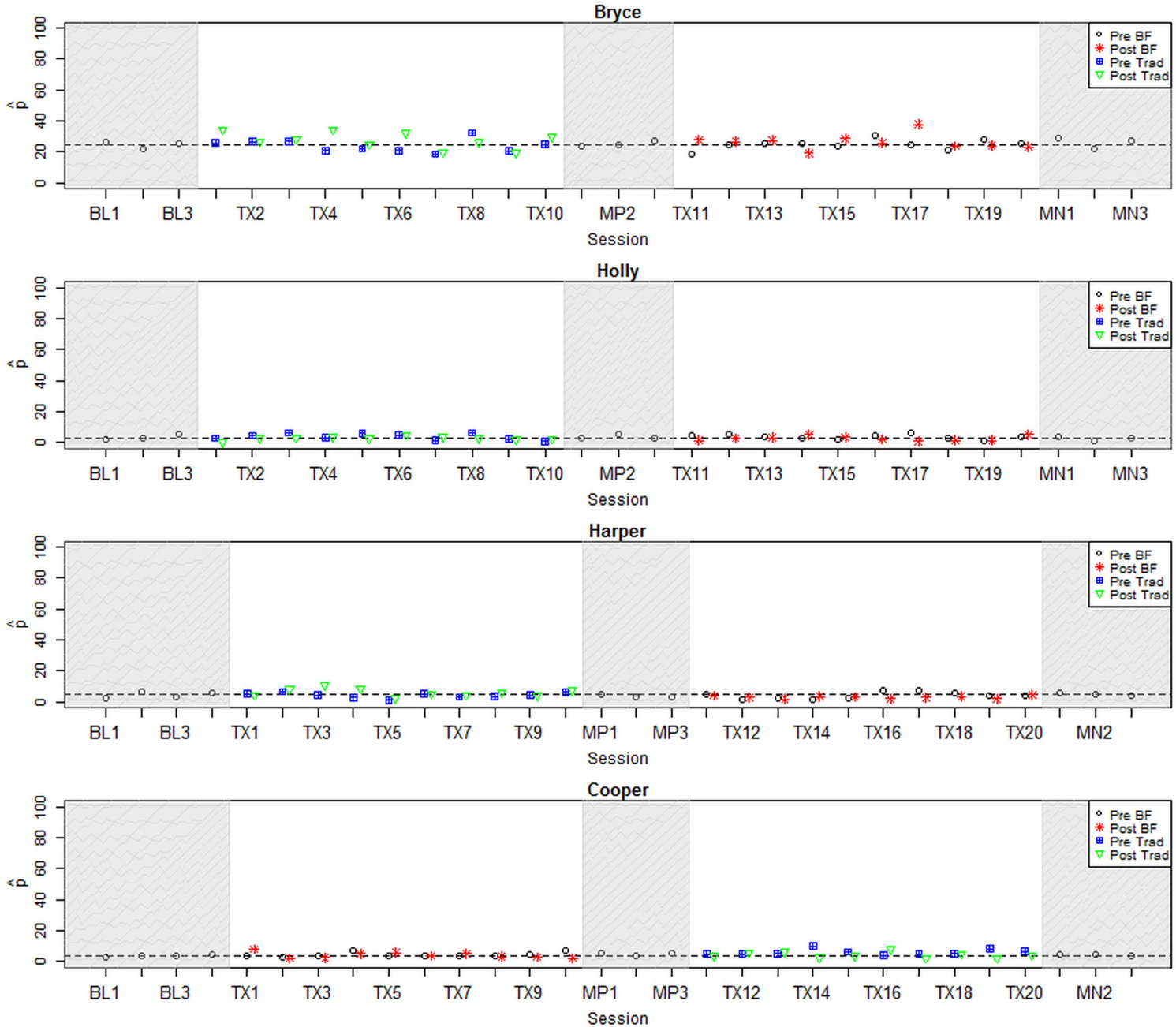
Study II: Strong responders



Study II: Moderate responders



Study II: Nonresponders



What does this tell us about efficacy of the combined treatment package?

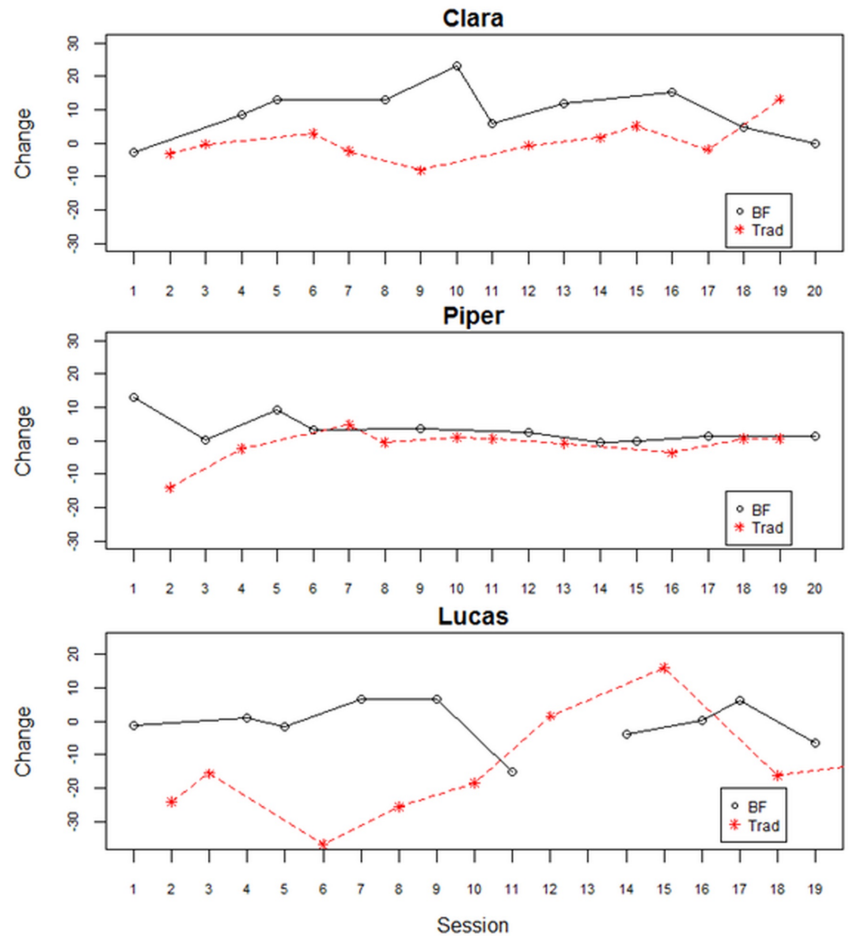
- Participants had previously received an average of 2-4 years of treatment without success.
- In this context, the amount of progress observed in 10 weeks of treatment suggests that the combined treatment package can be considered effective.
- However, the substantial number of non-responders makes it clear that this is not a “silver bullet" treatment solution.
- As in previous literature, problems arise at the level of generalization; even weakest responders showed progress within the treatment setting

Results: Short-term learning

- By comparing pre versus post probes within a session of a given type, we can track how much learning occurred in each session.
- Then we can make comparisons across session types.
  - In Study I, this was carried out as a within-subject comparison using randomization tests.
  - In Study II, this was carried out as an across-subjects comparison using mixed-effects regression.

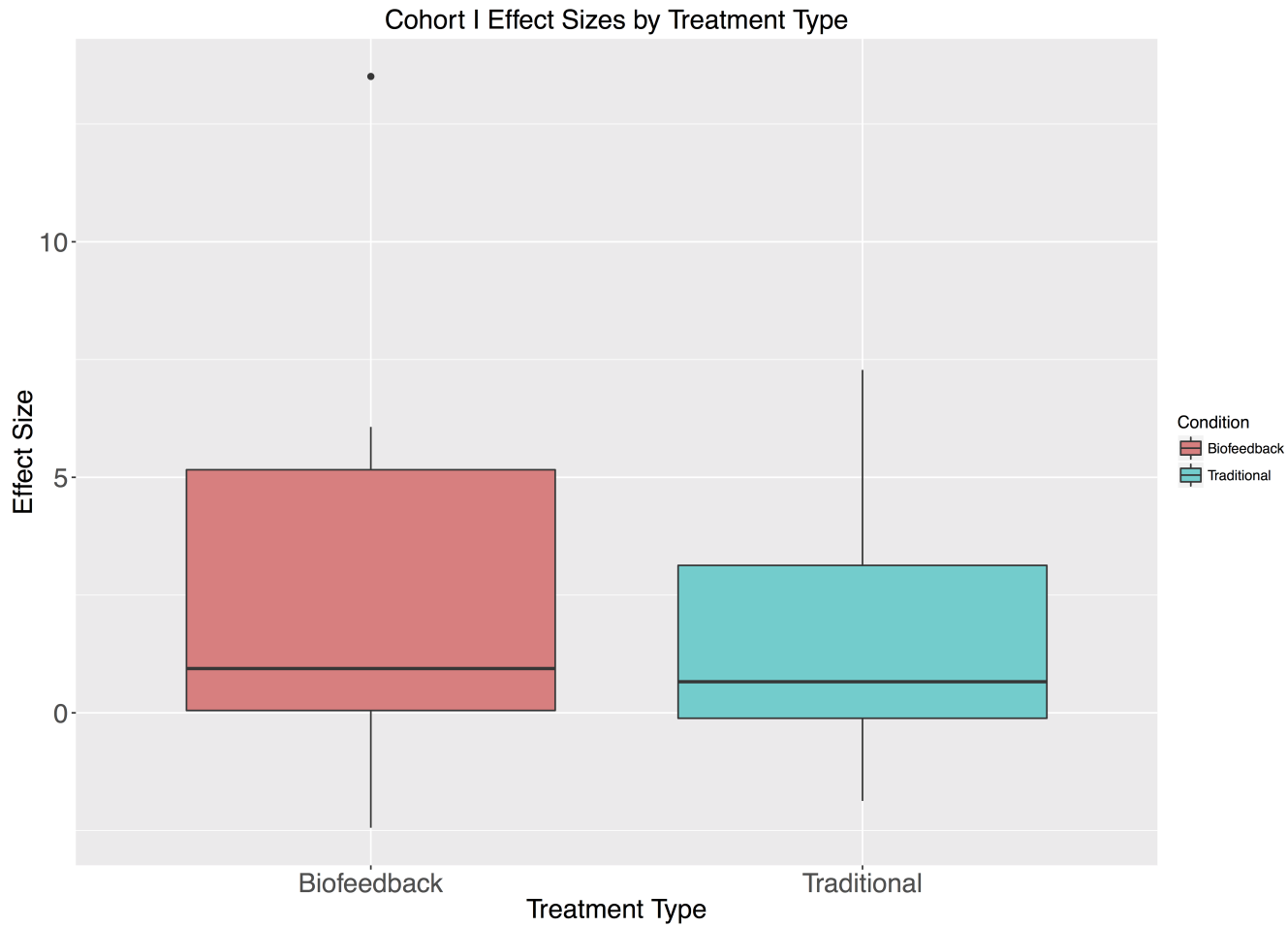
Results: Randomization tests (Study I)

- Three out of seven participants showed a significant difference in the magnitude of change in biofeedback versus traditional treatment sessions.
- All significant cases showed an advantage for biofeedback over traditional; none showed the reverse.



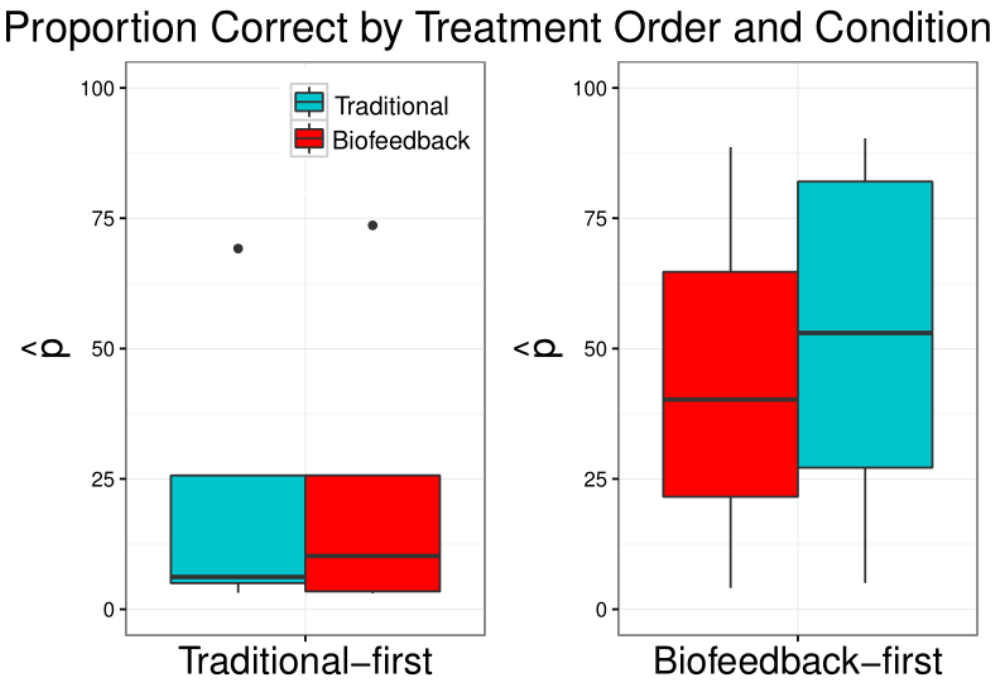
Results: Regression (Study II)

- Contrary to hypothesis, there was no significant difference in overall accuracy between biofeedback and traditional phases of treatment.



Results: Regression (Study II)

- However, there was a significant interaction between treatment type and treatment order.
- Suggests that an early phase of biofeedback may enhance progress in a subsequent phase of traditional treatment.
- This is consistent with expectations based on principles of motor learning (detailed KP feedback is expected to be most beneficial in early stages).



Interpretation

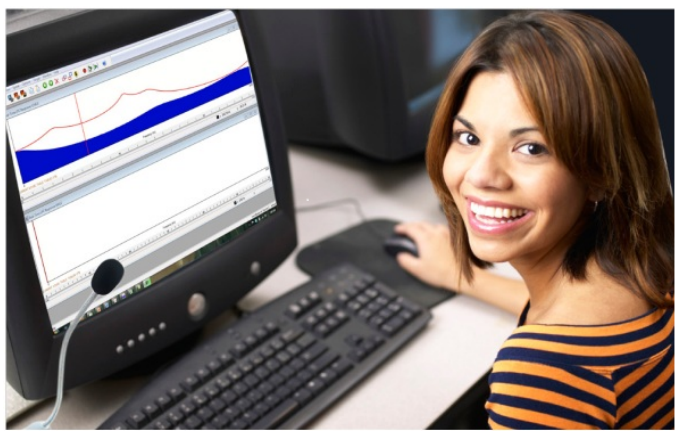
- What do these studies tell us about the relative efficacy of biofeedback versus traditional treatment?
- Neither one showed strong evidence of a difference between methods.
- However, results in both studies were suggestive of an advantage for biofeedback.
  - 3 significant randomization tests in Study I
  - Interaction suggesting facilitative effect of initial phase of biofeedback in Study II

Next steps

- Larger-scale studies (randomized controlled trials) are needed.
- Specifically investigate order of treatment application (biofeedback, then traditional) that is suggested by principles of motor learning and was supported by interaction in Study II
- Increase trials per session–older children can handle more than we were eliciting.

Other questions

- Compare visual-acoustic biofeedback versus other types of biofeedback, e.g. ultrasound.
- Look for individual predictors of treatment response (e.g. perceptual acuity) to explain the wide variation we see in response to biofeedback.
- Optimize dosage and scheduling–intensive practice might be better?



Making biofeedback widely available: staRt app

- Make app available to clinicians free of charge.
- Ask to be "paid in data."
  - Clinical partners provide treatment following a standard protocol.
  - Treatment interactions are recorded to device and, with permission, uploaded to our team.
  - Could give more children access to biofeedback while helping us carry out larger-scale efficacy research.
- Interested in getting involved? http://bit.ly/NYUstart

Thank you!

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Supported by: NIH R03DC 012883; NYU Research Challenge Fund; NYU Steinhardt Technology Award; NYU ABILITY Lab.

Thanks to: NYU ByunLab members.