Effects of Stuttering Frequency, Speaking Rate and Treatment on Speech Naturalness in Adults Who Stutter

Student Researcher: Emily Hausman
Chair: Stephen Tasko
Committee Member: Ronald Kelley
What is Stuttering?

- A speech disorder primarily characterized by intermittent disruptions of speech
- Includes
  - Sound, syllable and word repetitions
  - Sounds prolongations
  - Hesitations or pauses in speech (sometimes called blocks)
- Occurs 1% of the population
- Onset between 2-4 years of age
- Up to 80% will recover
- Physical characteristics can be associated with stuttering
  - Muscle tension, eye blinking, facial grimacing, avoidance of difficult words
  - Negative thoughts and feelings about stuttering and communication in general

The speech patterns of persons who stutter can sound **unnatural** to conversational partners.
Approaches to Stuttering Treatment

- Changing speaking behavior
- Reducing negative thoughts and feelings about stuttering and communication
- Approaches changing to speech/stuttering behaviors:
  - Stuttering modification: reduce severity of stutter
  - Fluency shaping: focus on fluency – altering manner of speaking
    - Slowed speech/altered speech rate
    - Easy onset voicing
    - Breath support
    - Rhythm control
    - Light contact of articulation
  - Research Evidence indicates that these treatments that focus on changing the manner of speaking can effectively reduce stuttering.

Following treatment persons who stutter can sound unnatural to conversational partners, in spite of being relatively fluent.
Why Speech Naturalness?

- Traditional measures of stuttering do not fully capture how much patterns call attention to themselves.
- Techniques learned in treatment can have the unintended consequence of speech patterns that sound unnatural to conversational partners.
- Clinical tools used to measure this:
  - Nine-point equal interval rating scale.

![Nine-point equal interval rating scale]

- Been a topic of interest of researchers for a long time.

From SSI-4
Impact of Stuttering on Speech Naturalness

Key Observations:

- Adults who stutter sound more unnatural than adults who do not stutter (Martin et al., 1984)
- Delayed Auditory Feedback (DAF) reduced frequency of stuttering but raters still found users of DAF to be more unnatural than AWNS (Martin et al., 1984)
- AWS sound unnatural after use of some stuttering treatments (Onslow et al., 1992)
- Naturalness ratings following treatment correlate with vowel duration and voice onset time (Metz et al., 1990)
Work Completed at WMU

- Work based on a large dataset of adults who stutter (and age matched controls) prior to and following participation in a stuttering treatment program (Tasko et al., 2007)

- Preliminary study revealed that post-treatment naturalness ratings on an oral reading task was negatively correlated with speaking rate (Jessen, 2016). This, along with previous research suggests that speech rate may be related to speech naturalness.

- Novelli (2018) demonstrated that a visual analog scale can be used to rate speech naturalness in persons who stutter.

- Previous studies have not attempted to examine how multiple variables (stuttering frequency, speech measures etc) may influence speech naturalness in stuttering.

- Aim of the current study:
  - Examine the relationship between stuttering frequency, **fluent syllable rate** and **speech pause duration** and speech naturalness in adults who stutter before and after treatment
Aims of this Study

Research Hypotheses:

- Pre-treatment speech samples rated as sounding less natural vs. post-treatment speech samples

- Speech naturalness ratings will be associated with stuttering frequency
  - Samples containing more stuttering will be rated as sounding more unnatural

- Speech naturalness ratings will be associated with fluent syllable rate
  - Samples spoken at slower fluent syllable rates will be rated as sounding less natural to listeners

- Speech naturalness ratings will be associated with mean pause duration
  - Speech samples containing greater pause durations will be rated as sounding more unnatural
Methods

Participants:
- Drawn from Walter-Reed-Western Michigan University Stuttering Database
- Reserve and active duty members of the United States Armed Services
- All participants reported to have stuttered since childhood
- Current participant pool: 34 participants (33 males: 1 females)
  - Mean age: 26 years old (age range: 19-42 years old)
Treatment Program

- The Walter Reed Stuttering Treatment Program
  - Intensive residential program
  - Group-based therapy

- Consists of three parts:
  1. Focus on speech production, characteristics of stuttering and attitudes/beliefs towards stuttering
  2. Focus on establishing speech behavior targets
  3. Provided settings and activities to transfer skills learned into other speaking situations

- Speech targets include abdominal breathing, increased breath support and volume, continuous airflow, easy phonatory and articulatory onset, and continuous phonation.

- Targets were established with the computer assisted fluency enhancement training (CAFET) program (Goebel, 1998), in which provides computerized feedback for respiratory and voice parameters.

- High quality video recordings of extended monologue, oral reading and phone conversation were made prior to and after completing the treatment. These served as the source for all subsequent analysis.

(Tasko et al., 2007)
Previously Collected Measures

Speech Naturalness Ratings (Novelli, 2018)

- 50 adults recruited as judges
- Each judge randomly assigned 38 video samples
- Samples judged included pre-treatment and post-treatment monologue and oral reading tasks
- Judges rated samples via digital “slider” that provided a visual analog rating
- Ratings averaged across panel of 12-13 listeners
  - Good to excellent inter-rater agreement
- Result is an integer between 0 (highly natural) and 1000 (highly unnatural)
Previously Collected Measures

Behavioral Analysis of Stuttering (Tasko et al. 2007)

- Two speech pathologists transcribed speech samples and identified and labeled disfluent events
- Results were then viewed together to compare
- Disagreements regarding transcription were settled by re-watching video samples and reaching a consensus
- The final consensus transcription organized by type of disfluency to derive a final count
  - Data used to derive estimates of stuttering frequency along with stuttering severity using the Stuttering Severity Instrument (Riley, 1994)
Measuring Pause Duration

- Pause duration was determined by gaps in acoustical energy larger than 250 milliseconds.
- To determine overall speech duration:
  - Time values measured at the beginning and end of each sample.
- After all pause events were identified, values were imported into MATLAB (Mathworks, Natick, MA).
  - Mean pause duration calculated.
Measuring Syllable Rate

- Fluent, stutter-free speech was identified to determine syllable rate
- Three fluent runs were labeled in each pre-treatment and post-treatment sample
- Transcripts of each sample were used to determine a syllable count
- Total syllable count of three speech intervals along with total duration of the three intervals was used to determine overall syllable rate
Data Analysis

- Data was analyzed using a STATA statistical analysis software (StataCorp, College Station, TX).
- Measurement agreement assessed using a two-way random effects intraclass correlation coefficient (ICC).
- Pre-treatment and post-treatment comparisons across the main measures were performed using a paired $t$-test.
- Linear regression analysis used to determine statistical relationships between speech naturalness ratings, stuttering frequency, mean pause time and fluent syllable rate.
- Naturalness ratings and stuttering frequency measures were submitted to a rationalized arcsine transform (RAU transform) (Studebaker, 1985).
Results

Measurement Agreement
- 7 speech samples (10%) were re-measured for pause duration
- Two-way random effects intraclass correlation coefficient (ICC) was used to assess rater reliability
- ICC value was .97 with a 95% confidence interval between .82 and .99
- These values are considered to be excellent
Results

Pre-treatment vs. Post-treatment Naturalness Ratings

- Post-treatment samples were rated as more natural than pre-treatment samples ($t$-statistic: $1.92; df=33; p=0.03$)
- Majority of data points located below line of equality suggesting that speech naturalness perceived as being more unnatural before treatment compared to after treatment
- Some data points located on or very close to line of equality suggesting no change
- Some data points are above the line indicating that post-treatment naturalness ratings are higher than pre-treatment
Results: Stuttering Frequency

Post-Treatment Percent Stuttered Words vs. Pre-Treatment Percent Stuttered Words

- Pre-treatment samples exhibited greater stuttering frequency relative to post-treatment samples ($t$-statistic: 10.18; $df=33$; $p<0.00005$).

- All data points located below under line of equality
  - Indicates that all participants showed some reduction in stuttering frequency
  - Higher stuttering frequency during pre-treatment samples
Results: Pause Duration & Syllable Rate

SYLLABLE RATE

- There was no mean difference between pre-treatment and post-treatment syllable rates ($t$-statistic: .4139; $df=33$; $NS$)

PAUSE DURATION

- Post-treatment pause durations were significantly longer than pre-treatment pause durations ($t$-statistic: -4.1145; $df=33$; $p=.0001$).

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</table>
Results

Speech Naturalness and Stuttering Frequency

- Pre-treatment
  - Strong, positive, linear relationship
  - Adjusted $R^2$: 0.62
  - $F(1, 32)$: 51, $p<0.00005$
  - Model accounts for 62% of the variance
Results

Speech Naturalness and Stuttering Frequency

- Post-treatment
  - No association between the two variables
  - \( R^2: 0.002, F(1, 32): 0.79, NS \)
  - Stuttering frequency very low in post-treatment samples
  - Speech naturalness not influenced by stuttering frequency
Results

Speech Naturalness and Syllable Rate

Pre-Treatment

- No evidence of relationship between two variables
- $R^2$: 0.02, $F(1, 32)$: 0.66, NS
- Syllable rate appears to have no relationship with speech naturalness prior to treatment

![Graph showing relationship between syllable rate and naturalness rating before treatment.](diagram.png)
Results

Speech Naturalness and Syllable Rate

Post-treatment

- No association between the two variables.
- $R^2$: 0.03, $F(1, 32)$: 0.86, NS
- Syllable rate of monologue samples are unrelated to listener ratings of speech naturalness during both pre and post-treatment
Results

Speech Naturalness and Pause Duration

Pre-treatment

- No linear relationship between the two variables
- $R^2$: 0.07, $F(1, 32)$: 2.56, NS
- During pre-treatment samples, subjects did not exhibit significant pauses in speech that impacted naturalness
- Pause duration had little effect on naturalness during pre-treatment data set
Results

Speech Naturalness and Pause Duration

- Post-treatment
  - Strong, linear relationship between two variables
  - $R^2: 0.55$, $F(1, 32): 39.44$, $p<0.00005$
  - Model accounts for 55% of the variance
  - After treatment, participants exhibit significant pauses in speech
  - Pause duration has a significant impact on speech naturalness ratings during post-treatment only
Summary of Findings

STUDY AIM 1
- Examine speech naturalness before and after treatment

HYPOTHESIS
- Pre-treatment samples will be rated as sounding less natural compared to post-treatment samples

SUMMARY OF FINDINGS
- Significant decrease in naturalness ratings from pre-treatment to post-treatment
- Adults who stutter sound more unnatural before treatment compared to after treatment
- However, there were some notable exceptions where post-treatment naturalness ratings were worse than pre-treatment naturalness ratings
Summary of Findings

STUDY AIM 2

- Examine the relationship between stuttering frequency and speech naturalness ratings

HYPOTHESIS

- Speech naturalness ratings will be associated with stuttering frequency where speech samples containing more stuttering will be rated as sounding less natural to listeners

SUMMARY OF FINDINGS

- Stuttering frequency had a strong relationship with speech naturalness ratings before treatment only
Summary of findings

STUDY AIM 3
- Examine relationship between syllable rate and speech naturalness ratings

HYPOTHESIS
- Speech naturalness ratings will be associated with syllable rate where speech samples that are spoken at slow syllable rates will be associated with unnatural speech

SUMMARY FINDINGS
- No difference in syllable rate between pre-treatment and post-treatment ratings
- No association between syllable rate and speech naturalness
Summary of Findings

STUDY AIM 4

- Examine the relationship between pause duration and speech naturalness ratings

HYPOTHESIS

- Speech naturalness will be associated with mean pause duration where samples containing greater pause durations will be rated as sounding more unnatural to listeners

SUMMARY OF FINDINGS

- Naturalness is rated significantly higher (more unnatural) for post-treatment pause duration as compared to pre-treatment pause duration
- Pause duration was found to be a significant predictor of post-treatment naturalness scores
Study Limitations and Future Research Directions

STUDY LIMITATIONS

1. Little gender variability
   1. Ratio (male to female) 33:1
2. Samples used were from a single stuttering treatment program
3. Results limited to one type of speaking task.

FUTURE RESEARCH DIRECTIONS

1. Expand acoustic analysis to assess other features of speech signal (e.g. prosody, rhythm)
2. Utilizing other treatment programs
3. Investigate if results generalize across speaking activities


Questions?