Investigating changes in connected speech in nonfluent/agrammatic primary progressive aphasia following script training

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Introduction

- **Primary progressive aphasia (PPA)**
  - progressive deterioration of speech and language

- **Nonfluent/agrammatic PPA (nfvPPA) consensus criteria** *(Gorno-Tempini, et al. 2011)*
  - characterized by
    - agrammatism in language production
    - motor speech impairment (apraxia of speech with or without dysarthria)
  - deficits can co-occur to varying degrees or appear in relative isolation
    - primary progressive apraxia of speech (PPAOS) *(Josephs, et al. 2012)*
    - progressive agrammatic aphasia (PPA-G) *(Thompson & Mack, 2014)*

- Limited treatment research in nfvPPA addressing linguistic and motoric deficits explicitly
Introduction

• Interventions from stroke-induced aphasia and AOS literature (Ali et al., 2018; Cherney et al., 2008, 2014; Cherney & Halper, 2008; Costello-Yacono & Balasubramanian, 2018; Goldberg et al., 2012; Grasso et al., 2019; Moss, 2009; Szabo et al., 2014; Youmans et al., 2005, 2011)
  • script training has the potential to address linguistic and motoric deficits in nfvPPA

• Video-Implemented Script Training for Aphasia (VISTA) has been shown to be effective for individuals with nfvPPA (Henry et al., 2018)
  • results indicated significant improvement in accurate script production at post-treatment
  • improvements in intelligibility
  • reduction of grammatical errors
Introduction

• Analysis of connected speech allows for evaluation of speech in contexts that more closely resemble real-world communicative conditions
  • time-intensive
  • required expertise

• Computerized Language ANalysis (CLAN) (MacWhinney, 2000)
  • Quantitative Production Analysis (Saffran et al., 1989)
    • c-QPA (Fromm et al., 2020)
  • Northwestern Narrative Language Analysis (Thompson, 2013)
    • c-NNLA (Fromm et al., 2020b)

• Script-training studies have examined a handful of measures of connected speech beyond accuracy of scripted content
  • speech rate (Ali et al., 2018; Cherney et al., 2008, 2014; Cherney & Halper, 2008; Costello-Yacono & Balasubramanian, 2018; Goldberg et al., 2012; Moss, 2009; Szabo et al., 2014; Youmans et al., 2005, 2011)
  • intelligibility (Grasso et al., 2019; Henry et al., 2018)
  • disfluencies (Goldberg et al., 2012; Youmans et al., 2005)
  • % different words produced (Fridriksson et al., 2012)
  • number of grammatical errors per 100 words, % words with grammatical morphemes, subject-verb-object structure production (Grasso et al., 2019; Henry et al., 2018; Goldberg et al., 2012; Costello-Yacono & Balasubramanian, 2018)
Introduction

• We aimed to extend the findings of Henry et al., 2018 by investigating additional treatment-sensitive outcome measures in a larger sample
  • speech fluency
  • grammar
  • informativeness

• We predicted:
  • trained script topics would show a significant difference from pre- to post-treatment
  • changes would differ significantly between trained and untrained script topics from pre- to post-treatment with trained topics demonstrating greater change
    • potential for generalization to untrained topics at the individual level
Participants

- 20 individuals (10 from Henry et al., 2018) meeting 2011 consensus criteria for nfvPPA
- all participants demonstrated motor speech impairment
- 14 demonstrated impaired expressive grammar on standardized testing and in connected speech

Demographics and Speech/Language and Cognition Scores at Pre-Treatment

<table>
<thead>
<tr>
<th></th>
<th>mean (SD)</th>
</tr>
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<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>68.45 (5.8)</td>
</tr>
<tr>
<td>Sex</td>
<td>12 female, 8 male</td>
</tr>
<tr>
<td>Years of Education</td>
<td>16.65 (2.6)</td>
</tr>
<tr>
<td>Handedness</td>
<td>19 right, 1 left</td>
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<tr>
<td><strong>Speech, Language and Cognition</strong></td>
<td></td>
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<tr>
<td>Mini-Mental State Examination (30)</td>
<td>27.3 (2.4)</td>
</tr>
<tr>
<td>Western Aphasia Battery AQ (100)</td>
<td>86.42 (9.0)</td>
</tr>
<tr>
<td>PPVT-short (16)</td>
<td>14.78 (2.0)</td>
</tr>
<tr>
<td>AOS rating(^a) (0=none - 7=profound)</td>
<td>3.2 (1.2)</td>
</tr>
<tr>
<td>Dysarthria rating(^a) (0=none - 7=profound)</td>
<td>1.85 (1.7)</td>
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<td>Northwestern Anagram Test (%)</td>
<td>64.39 (21.8)</td>
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\(^a\) from Wertz et al. (1984); AQ = Aphasia Quotient, PPVT = Peabody Picture Vocabulary Test, AOS = Apraxia of Speech
Methods

- Participants were treated using VISTA
  - six individualized scripts were developed for each participant in a collaborative process
    - four scripts entered treatment one at a time; two remained untrained
    - scripts were balanced for linguistic measures of grammar and complexity
  - speech samples collected pre-treatment informed the length, complexity, and rate of the scripts
    - Cat Rescue picture description
    - Grandfather Passage reading
    - speech in response to open-ended questions
  - scripts were treated in twice weekly sessions with a clinician
  - video stimuli were created for the scripts
  - homework consisted of unison speech production practice (speech entrainment, Fridriksson et al., 2012) for 30 minutes/day with video of their script

Example Scripts from 2 Participants

**Dancing**
I like to dance a lot. I memorize many routines. My husband and I do competitive country western dancing. We do eight different dances.
(66 wpm)

**Primary Progressive Aphasia**
I have primary progressive aphasia, which is a speech problem caused by tau protein in the brain. My speech is no longer fluid or reflexive. Words with more than two syllables are difficult for me. I have to think about what to say before speaking. Please be patient and let me have extra time to talk.
(87 wpm)
• Probes eliciting responses to script topics were conducted twice pre-treatment and post-treatment

Methods

Pre-TX Probe for script topic: Stocks
Clinician: “Tell me about stocks.”
Participant: “I been uh working on stocks for twenty years. Need...uh need some money for the stocks. Bif...uh dih...up...uh deposit for...uh...posit...uh back and forth you know. But uh...”

Post-TX Probe for script topic: Stocks
Clinician: “Tell me about stocks.”
Participant: “I been uh purchase stocks for two decades. I want dividends there four percent or higher. I want uh talk to my stock broker every day which stocks to buy. I wait for my stock broker’s report could make a decision. Are you interested in the stock market?”
Methods

• Responses to script probes were transcribed and coded using CHAT (Codes for the Human Analysis of Talk, MacWhinney, 2000) & CLAN
  • trained undergraduate and graduate research assistants blinded to timepoint
  • reliability conducted on one time point for each participant
  • coding in CLAN by trained graduate research assistant

• Transcriptions were analyzed using CLAN for:
  • mean length of utterance in morphemes (MLUm)
    (Nobis-Bosh et al., 2011; increase in script-related morphemes: Cherney et al., 2008; Cherney and Halper 2008)
  • words per minute (WPM)
    (Ali et al., 2018; Cherney et al., 2008, 2014; Cherney & Halper, 2008; Costello-Yacono & Balasubramanian, 2018; Goldberg et al., 2012; Moss, 2009; Szabo et al., 2014; Youmans et al., 2005, 2011)
  • fluency disruptions per hundred words* (Goldberg et al., 2012; Youmans et al., 2005)
  • proportion of open to closed class words
    (Ash et al., 2010; Thompson et al., 1997; Wilson et al., 2010; Nobis-Bosh et al., 2011)
  • propositional idea density
    (stroke-induced nonfluent aphasia: Bryant et al., 2013; Ferguson et al., 2013; Fromm et al., 2016; Ulatowska et al., 1981, 1983; distinguishing between PPA subtypes: Vander Woude, 2017)
  • grammatical complexity index
    (improved production of grammatical morphemes: Cherney et al, 2008; Cherney & Halper, 2008; Goldberg et al., 2012; production of more SVO structures: Costello-Yacono & Balasubramanian, 2018)

• Percent correct intelligible scripted words

* Indicates measures which require additional coding beyond transcription in CLAN
Methods

• For each measure, data for each script for two observations at each time point from pre-treatment and post-treatment were used in the analysis

• A series of mixed-effects linear regression models with a fixed effect of timepoint and a random intercept for participant
  • to infer specificity of observed training effects
    • mixed-effects linear regression models with an interaction term of time (pre and post-treatment) and condition (trained and untrained) and a random intercept for participant were performed
  • trained script topics assessed via one-tailed tests
  • untrained script topics assessed via two-tailed tests
Fixed Effect of Time on Script Accuracy and Interaction of Time and Training Condition

![Graphs showing the effect of time on script accuracy for trained and untrained topics.](image-url)
Fixed Effect of Time on Measures for Trained Topics

- **Words per Minute**
  - Pre: 55
  - Post: 70

- **Fluency Disruptions per 100 Words**
  - Pre: 25
  - Post: 15

- **MLU in morphemes**
  - Pre: 11
  - Post: 12

- **Grammatical Complexity Index**
  - Pre: 0.07
  - Post: 0.09

- **Proportion of Open to Closed Class Words**
  - Pre: 0.44
  - Post: 0.46

- **Propositional Density**
  - Pre: 0.46
  - Post: 0.48
Fixed Effect of Time on Measures for Untrained Topics

- Words per Minute
- Fluency Disruptions per 100 Words
- MLU in morphemes
- Grammatical Complexity Index
- Proportion of Open to Closed Class Words
- Propositional Density
Interactions of Time and Training Condition

**Words Per Minute**
- Pre: 55
- Post: 65
- Trained: Red
- Untrained: Blue

**Fluency Disruptions per 100 Words**
- Pre: 20
- Post: 15
- Trained: Red
- Untrained: Blue

**MLU in morphemes**
- Pre: 10
- Post: 12
- Trained: Red
- Untrained: Blue

**Proportion of Open to Closed Class Words**
- Pre: 0.9
- Post: 1.1
- Trained: Red
- Untrained: Blue

**Grammatical Complexity**
- Pre: 0.07
- Post: 0.09
- Trained: Red
- Untrained: Blue

Note. Each model includes a random intercept for participant. The y axis presents fitted values from the linear mixed effects model. Standard error is shown in shaded color along the fitted regression line.
Discussion

• Complementing previous findings (Henry et al., 2018), we found improvements for trained topics on measures examining:
  • grammar (grammatical complexity, MLU\textsubscript{m}, proportion of open to closed class words)
  • speech fluency (fluency disruptions)
  • speech rate (WPM)

• Script training has the potential to yield improvements for individuals who present with deficits in grammar and/or motor speech (i.e., apraxia of speech)

• Small numerical improvements were observed for untrained topics on our outcome measures
  • not statistically significant
    • variable numerical improvements at individual level
  • suggests greatest benefit of script training is observed for practiced material

• Relatively automated calculation of connected speech measures which were sensitive to treatment in this population hold potential for application in clinical settings
Future Directions

• Examine potential differential effects for individuals with relatively isolated deficits (motor speech vs. agrammatism) versus mixed phenotypes

• Examine whether treatment-induced improvements on relevant outcome measures generalize to other connected speech tasks

• Evaluate relatively automated analysis methods in conjunction with automatic speech recognition to further reduce time-demands

• Employ acoustic analysis to further inform treatment effects
Next Step: Acoustic Analyses

• Articulatory and prosodic metrics differentiate between nfvPPA and logopenic PPA in connected speech samples *(Haley et al., 2021)*

• Speech timing measures show a significant and specific effect of treatment for trained topics
  • syllables per second of phonated time (articulation rate)
  • mean time between syllable onsets
  • mean pause duration
  • speech-to-pause ratio
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