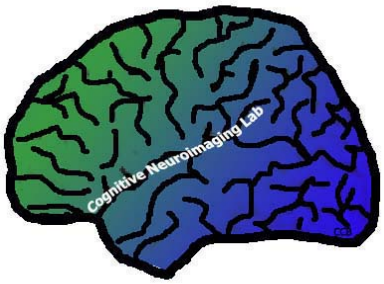

SpeechEasy: Altered auditory feedback in Adults with Persistent Developmental Stuttering

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Abstract

The purpose of this proposed study is to assess how one widely-marketed device for the treatment of stuttering (i.e., SpeechEasy) influences stuttering in adults with persistent developmental stuttering (PDS). The first experiment is designed to examine specific parameters (delayed auditory feedback-DAF, frequency altered feedback-FAF settings, Ear Placement-Right versus Left Ear) on amelioration of stuttering. A second experiment is designed to determine whether there is a relationship between atypical auditory temporal anatomy and response to altered auditory feedback (SpeechEasy) in adults with PDS. Results of the proposed project should have important theoretical, and therapeutic implications for the use of such devices to treat stuttering in adults who stutter. Future studies may propose to examine mechanisms of treatment of stuttering with the SpeechEasy in children with PDS.

EXPERIMENT 1: Influence of Altered Auditory Feedback on Stuttering

Background and Significance

There are numerous reports regarding the use of altered auditory feedback to enhance fluency in individuals with developmental stuttering (e.g., Armson, Kiefte, Mason, & DeCroos, 2006; Stuart, Kalinowski, Armson, Stenstrom & Jones, 1996; Van Riper, 1973, pp. 116-139). These alterations have involved such procedures as low-pass and high-pass auditory masking (e.g., Conture, 1974), delayed auditory feedback (DAF) (Van Riper, 1973), and frequency altered feedback (FAF) (Armson et al., 2006). To greater or lesser degrees, these various alterations in speaker's auditory feedback for speech have been shown to reduce stuttering during reading as well as conversational speech.

With recent advances in digital technology, however, one such device has been widely marketed and empirically studied, that is, the SpeechEasy (2001), a small device that can be worn like a hearing aid. This device can be adjusted in terms of DAF as well as FAF parameters. According to SpeechEasy's associated marketing literature, such adjustments or alterations in auditory feedback for speech supposedly mimic the effects of choral reading. One empirical study (Armson et al., 2006) showed that the SpeechEasy reduced stuttering events by 49%, 36%, and 74% respectively for conversation, monologue, and reading. Fluency was even more enhanced in all speaking conditions with the instruction to deliberately prolong vowels.

Thus, the purpose of this project is to assess how one widely-marketed device for the treatment of stuttering (i.e., SpeechEasy) influences stuttering in adults with persistent developmental stuttering (PDS).

Method

Participants: Participants will include to right-handed adult males with a diagnosis of PDS, ages 20 to 40 years of age and a group of fluent controls. All participants will be native English speakers of comparable, educational, and occupational (i.e., socioeconomic) status. Groups will be matched for age, education, and socioeconomic status. Twelve adult participants will be recruited and prescreened for stuttering severity to assure that the sample includes individuals with mild (n=4), moderate (n=4), and severe (n=4) stuttering.

Individuals with significant neurological or psychiatric condition will be excluded as well as individuals with acquired stuttering (i.e., individuals whose stuttering is known or reported to begun as an adult, typically with a rapid or sudden onset following a physical or psychological trauma). PDS participants will be excluded if they have a history of prior treatment with altered audio feedback (DAF, FAF). History of prior speech therapy will be recorded, and individuals will be excluded if they have had speech therapy within six months of enrollment in the proposed studies.

Classification of Stuttering: To be considered a PDS for purposes of this study, each individual will fulfill the following criteria: (1) speech-language pathologist's judgment of the current presence of stuttering with a rating of 2 ("mild") or greater, (2) current conversational speech that contains three stuttering-like disfluencies (SLD) or within-word disfluencies per 100 words, and (3) stuttering continually present with the onset before 8 years of age. These assessments of the presence and severity of stuttering as well as classification of being a PDS will be based on a 1000-word sample (Sawyer & Yairi, 2006) of each participant's loosely-structured conversation with another adult.

Standardized Measures of Intelligence, Linguistic, & Motor Functions: To screen for intelligence within normal limits, the Wechsler Abbreviated Scale of Intelligence (WASI) (Psychological Corporation, 1999) will be employed. To screen for speech and language within normal limits, the Oral and Written Language Scales (OWLS) and the Oral Speech Mechanism Screening Examination- Revised (OSMRE-R) (Pro-Ed, 1987) will be used. To assess hand preference & motor performance, the handedness inventory, Finger tapping test, and Purdue pegboard test will be administered to all participants according to standardized procedures.

Audiological Screening Test: To screen for hearing sensitivity within normal limits (no threshold poorer than 20 dB HL), a pure tone audiometric evaluation will be completed. Hearing thresholds for each ear will be assessed at frequencies between 250 and 8000 Hz (Grason-Stadler-GSI 61 Audiometer). Participants with a hearing loss or threshold differences between the ears of greater than 10 dB on any of the frequencies tested will be excluded from participation. To further screen the normalcy of the participants' central and peripheral auditory system, tympanometry as well as central auditory reflex testing will be completed. Any participant who exhibits central or peripheral concerns will be excluded from further consideration.

Experimental Procedures: Participants will be examined without the device in place (baseline condition) and pre- and post-fitting in each of two experimental conditions. These studies are designed to answer essential, basic questions about the effectiveness of this device under a variety of controlled conditions. The study is a within-group (i.e., within-PDS) design to compare baseline speaking to experimental conditions with the device in place.

The conditions include: baseline and two experimental conditions. The experimental conditions will be repeated with the device in the right and left ear. This design results in five conditions. All participants will be examined under all conditions in a randomized order. The baseline speech sample will be acquired before any of the experimental conditions. Speech samples will be audio and video recorded for subsequent analyses.

All participants will be examined in two sessions: one session involving pre-test speech-language usage, audiometric, etc. screening and the second session involving all five conditions. Stuttering events will be examined in conversational speech during monologue (1,000 words) and dialogue (1,000 words). Based on descriptions elsewhere (e.g., Pellowski & Conture, 2002), instances of stuttering that occur during these conditions will be defined as: part-word and whole word repetitions, part-word prolongations, and inaudible postural fixations. The baseline and four experimental conditions are listed below:

- *Condition 1 Baseline (No device)* – Participant produces speech samples. The device is not in place at baseline.
- *Condition 2 (Experimental: Manufacturer's Settings)* Right Ear – Participant wears the device with alterations set to the manufacturers default setting (DAF 60msec, FAF +500Hz)
- *Condition 3 (Experimental: Individual Settings)* Right Ear – Participant wears the device with alterations set to individually prescribed settings (DAF & FAF).
- *Condition 4 (Experimental: Manufacturer's Settings)* Left Ear – Participant wears the device with alterations set to the manufacturers default setting (DAF 60msec, FAF +500Hz)
- *Condition 5 (Experimental: Individual Settings)* Left Ear – Participant wears the device with alterations set to individually prescribed settings (DAF & FAF).

Data Analysis: Mean stuttering frequencies will be computed for each speaking task (dialogue and monologue) at baseline and during each of the four conditions. Raw stuttering frequencies will be averaged between monologue and dialogue samples per each condition as well as for each of the two samples for each of the 4 conditions. Resulting data will be used to calculate a derived or change score for each condition using the following formula: (Condition 1 – Baseline)/ (Condition 1 + Baseline). Group and individual performance profiles will be examined in relation to baseline output and will be computed as a proportion of utterances (stuttering events in the first 300 words in each speaking condition).

EXPERIMENT 2: Developmental Stuttering: The Anatomical Basis of Altered Auditory Feedback

Background and Significance

The proposed studies will focus on the central auditory system, and will extend our prior research that found a relationship between the anatomy of auditory temporal cortex (planum temporale, PT) and response to delayed auditory feedback (DAF) (Foundas et al, 2004). The current studies will be limited to right-handed men (20-40 years) who do and do not stutter in order to learn about these neural systems in developed adults. The results of the proposed experiments will not allow us to determine the cause of stuttering, but we should be able to learn more about the function and anatomy of auditory cortex and related brain regions in adults with persistent developmental stuttering (PDS), and in fluent, matched controls.

It is hypothesized that there will be a relationship between atypical auditory temporal anatomy and response to altered auditory feedback (SpeechEasy Device). Right-handed men who stutter (n=20) will be divided into two groups with ten individuals in each group: (1) PDS adults with a response to the use of the SpeechEasy device (PDS Treatment Positive Group), and (2) PDS adults who did not have a response to the use of the SpeechEasy device (PDS Treatment Negative Group). Based on results from our prior studies, we hypothesize that the PDS Treatment Positive Group will have atypical PT anatomy (rightward asymmetry or symmetry), whereas the PDS Treatment Negative Group will have typical PT anatomy (leftward asymmetry). We will also determine whether there is a relationship between primary auditory cortex (Heschl's gyrus - HG anatomy) and treatment response. Our prior studies did not study HG anatomy in adults with PDS.

Method

Participants: Right-handed men who stutter (n=20) will be divided into two groups with ten individuals in each group: (1) PDS adults with a response to the use of the SpeechEasy device (PDS Treatment Positive Group), and (2) PDS adults who did not have a response to the use of the SpeechEasy device (PDS Treatment Negative Group). A group of healthy, fluent controls (n=20) will also participate. Groups will be matched for age, education, and socioeconomic status. Groups will not necessarily be matched on stuttering severity or family history of stuttering.

Classification of Stuttering: Criteria described above in Experiment 1 will be used to determine PDS.

Standardized Measures of Intelligence, Linguistic, and Motor Functions: Tests described in Experiment 1 above will be administered to the adults with PDS and matched controls.

MRI Scan Acquisition & Rules of Measurement: Volumetric MRIs will be acquired on a GE 1.5 Tesla Signa Scanner with a T1-weighted spoiled GRASS sequence, as a gapless series of 124 contiguous sagittal images (1.5 millimeter thickness, FOV=240, 10^0 flip angle, 1 excitation, 256 x 256 pixel matrix). Images will be stacked and measured using the ANALYZE program (Mayo Clinic, 1986) to form the full 3D images. All MRI datasets will be assigned a blind number, and will be re-aligned to correct for head rotation in sagittal, axial and horizontal planes. Half of the MRIs will be randomly selected and hemispheres will be flipped (so right & left are reversed). These formatting procedures are performed to assure that measurements are performed blind to group, sex, handedness and hemisphere. Reliability has been established in our lab, with intra-class correlations >85% for each ROI. Inter- and intra-rater reliability will be re-established on the measurements described below in a sub-sample of controls before the formal experimental measurements commence. Measures will be done in the sagittal plane; orthogonal views will be used to assist in the determination of landmarks/boundaries for ROIs.

For each ROI, surface areas (SA) (gray matter, white matter) will be measured in consecutive images throughout the full extent using a computer-guided cursor to trace the cortical surface, conforming to the topography of the gyrus, including the depth of the sulcus except when adjacent sulci are closely opposed. Volumes will be calculated by summing areas in successive sections and multiplying by slice thickness.

Left and right hemisphere measures will be computed for each ROI in each subject, and AQs will be computed using the formula: Left-Right/[0.5(Left+Right)]. AQs have been used to control, in part, for head size, and to look at interhemispheric size differences. Ordinal measures have been used in the past to classify structures as: leftward AQ >+.025, rightward AQ > -.025, with symmetry in between these measures (5% inter-hemispheric size difference significant). AQs will also be defined along a continuum in some analyses. Volume and AQs allow us to examine the direction and magnitude of hemispheric differences. Total brain volume (TBV) will be measured by tracing the outer boundary of the cerebral hemisphere. Left and right hemisphere volumes will be

computed, and each ROI will be calculated as a raw volume and proportional to hemisphere volume so that absolute and proportional volumes can be compared.

Anatomy of Auditory Temporal Cortex – MRI Morphometry Measures
The auditory temporal cortical regions include two distinct subregions: Heschl's gyrus and the planum temporale. These regions will be measured in the left and right hemisphere in each participant. Anatomical boundaries are described below.

HG (Heschl's gyrus): Primary auditory cortex, Brodmann's Area 41-42, is located rostral to the PT with the transverse sulcus the anterior boundary and Heschl's sulcus (HS) the posterior boundary. HG is often bifurcated by an intermediate sulcus. If fully split into two separate gyri in the sagittal plane, only the 1st HG will be included because when present a 2nd HG is transitional cortex morphologically more similar to auditory association cortex. Results regarding asymmetry have been conflicting; our recent study showed a leftward asymmetry in healthy men and a rightward asymmetry in healthy women (Knaus et al, 2005).

PT (Planum temporale): Auditory association cortex, Brodmann's area 22, is located along the temporal bank of the Sylvian fissure (SF), on the surface of the superior temporal gyrus, extending from the 1st HS to the end of the horizontal SF. The endpoint of the horizontal SF is demarcated by the bifurcation into an ascending and descending ramus. Post-mortem and MRI-based measures of the PT show a typical leftward PT asymmetry in 72% of healthy adults. Symmetry or a rightward PT is atypical.

Data Analysis and Interpretation: Hypotheses will be tested using ANOVA, with Group (PDS Positive Treatment Group, PDS Negative Treatment and PT AQ (R>L, L>R) entered as grouping factors. PT AQs will be computed using the formula: [(Left – Right) / [(0.5)(Left + Right)]. When the PT is larger in the left hemisphere (L>R) the AQ is positive, and when the PT is larger in the right hemisphere (R>L) the AQ is negative. A leftward PT asymmetry is typical and a rightward PT asymmetry is atypical. We have not related HG or HG+PT asymmetries to DAF. These anatomical variables will also be examined.

Post-Hoc Studies & Correlation Analyses: A series of post-hoc analyses will be conducted to examine competing hypotheses, structure-function relationships, and to identify potential behavioral-anatomical subgroups that may have been obscured in the group analyses. These results should complement the analyses described above and may yield important results for future studies. We have not yet determined whether stuttering severity or language deficits may be related to the number or type of anatomical anomalies. Correlation analyses will be conducted to examine these potential relationships. Standardized measures of motor functions, including oromotor functions and hand performance (dexterity and skill), will also be correlated with anatomical measures. Because we hypothesize that subgroups may emerge within both the stutter and control groups, we will conduct cluster analyses to test these hypotheses more fully. Examining only group means may also obscure distinct anatomical features. Thus, discriminant function analyses will be performed to identify whether specific variables such as language measures (auditory comprehension, output), stuttering severity, and estimates of intelligence, attention, or motor functions predict stuttering. We will also examine AQs across all ROIs to determine whether magnitude of asymmetry differs between groups. In addition, 95% confidence intervals (CIs) will be computed for the controls for each ROI, and will be used to determine whether individuals who stutter are more likely to fall above or below the controls' CIs. In this way we can examine the hypothesis of whether extreme size or asymmetry (or symmetry) exists in any stutter groups or clusters.

Limitations of Clinical-Anatomical Studies Our approach addresses how individuals with PDS differ from those without PDS on anatomical measures. There are limitations to this type of clinical-anatomical study. First, atypical asymmetries, reduced or increased size, or qualitative differences within anatomical regions do not necessarily confirm that these sites do not produce the symptoms, nor do they affirm that any specific anatomical site represents the underlying defect. Ideally, functional neuroimaging measures would be compared to anatomical measures using a ROI approach, which would provide a method to directly examine the degree of overlap between functional representations and the anatomical substrate. We are conducting pilot studies in this area in preparation for future grant proposals that will investigate these important relationships. Our MRI methods do not warp brains into standard space, but maintain brains in real-space. In addition these methods are not automated measures. This MRI morphometry approach maximizes the ability to detect subtle differences. Finally, these studies cannot confirm whether anatomical anomalies in the PDS group are the cause or the consequence of stuttering. Investigations of children, especially longitudinal studies, are needed to more directly answer this important question.