Investigations Of The Impact Of Altered Auditory Feedback In-The-Ear Devices On The Speech Of People Who Stutter: Initial Fitting And Four-Month Follow-Up

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Abstract

Background: Self-contained ear-level devices delivering altered auditory feedback (AAF) for the application with those who stutter were only recently developed (Stuart *et al.* 2003).

Aim: This paper examines the first therapeutic application of self-contained ear-level devices in three experiments. The effect of the device on the proportion of stuttered syllables and speech naturalness was investigated following initial fitting and at four-months post-fitting.

Methods and Procedures: Three experiments were undertaken: In Experiment 1, the effect of a self-contained in-the-ear device delivering AAF was investigated with those who stutter during reading and monologue. Two adolescents and five adults who stuttered read and produced monologue with and without a device fit monaurally. The device provided a frequency shift of plus 500 Hz in combination with a delayed auditory feedback of 60 ms. Custom made in-the-canal and completely-in-the-canal devices were fabricated for four adults and four youth in Experiment 2. The effect of group (i.e., youth vs. adult), time (i.e., initial fitting vs. four months follow-up), speech task (i.e., reading vs. monologue), and device (i.e., present vs. absent) on stuttering rate was examined. In Experiment 3, 15 naïve listeners rated the speech naturalness of speech produced by the participants in Experiment 2. Speech samples from six conditions were rated: reading and monologue without the device at the initial visit, reading and monologue with the device at the initial visit, and reading and monologue with the device at four months.

Outcomes and Results: In Experiment 1, the proportion of stuttered syllables was significantly (p = 0.011) reduced by approximately 90% during reading and 67% during monologue with the device relative to no device. Only a significant main effect of device (p = 0.0028) was found in Experiment 2. That is, stuttering rate was significantly reduced with the device in place regardless of speech task or group and remained so four months later. In Experiment 3, speech samples generated while wearing the device were judged to be more natural sounding than those without the device (p < 0.0001) for reading and monologue with both adults and youth. There was no significant difference between the mean naturalness ratings of speech samples generated during the initial fitting with the device relative to that at four months with the device (p > 0.05) in all cases except with the youth while engaged in monologue. For that condition, raters judged the speech produced at the initial fitting as more natural.

Conclusions: These findings support the notion that a self-contained in-the-ear device delivering AAF assists those who stutter: With the device in place, stuttering is reduced and speech produced is judged to be more natural than with out the device.

Investigations Of The Impact Of Altered Auditory Feedback In-The-Ear Devices On The Speech Of People Who Stutter: Initial Fitting And Four-Month Follow-Up

The fact that stuttering is reduced when individuals who stutter speak under conditions of altered auditory feedback (AAF) has been evident for more than 45 years. Conditions of AAF known to reduce stuttering relative to nonaltered auditory feedback (NAF) include delayed auditory feedback (DAF, Naylor 1953, Chase *et al.* 1961, Kalinowski *et al.* 1993, 1996, 1999, MacLeod *et al.* 1995), frequency-altered feedback (FAF, Howell *et al.* 1987, Kalinowski, *et al.* 1993, Hargrave *et al.* 1994, MacLeod, *et al.* 1995, Stuart *et al.* 1996, 1997a, Armson and Stuart 1998), masked auditory feedback (MAF, Shane 1955, Maraist and Hutton 1957, Kalinowski *et al.* 1993), and reverberation (Adamczyk *et al.* 1975, 1979, Smolka and Adamczyk 1992). MAF has been shown to be less efficient in reducing stuttering than DAF and FAF (Howell *et al.* 1987, Kalinowski *et al.* 1993). Kalinowski and colleagues (Kalinowski *et al.* 1993, MacLeod *et al.* 1995) have reported DAF and FAF to be equally effective in reducing stuttering while Howell and colleagues in their seminal paper (Howell *et al.* 1987) reported FAF to be more effective than DAF. Traditionally, forms of AAF have been generated by electronic signal processing devices, however, passive mechanical devices may produce AAF effects as well (Stuart *et al.* 1997b).

The method in which AAF reduces stuttering remains undetermined. It was originally speculated that those who stutter had an abnormal speech-auditory feedback loop. It was thought that this abnormality was corrected or bypassed while speaking under DAF. Numerous models were proposed to describe the nature of the potential cause/effect relationship (Cherry and Sayers 1956, Mysak, 1966, Webster and Lubker, 1968). Following the initial excitement, the importance of audition in stuttering was, however, diminished. The auditory system was discounted as an etiologic factor in stuttering based, in part, on the argument that it was too slow for on-line correction of speech (Borden 1979). This notion has since been challenged, as well (Stuart *et al.* 2002). Imaging studies have implicated the role of the auditory system on a central level and on a time scale compatible with the behavioral effects of DAF on the overt manifestations of the disorder. It was also argued that the fluency enhancing properties of DAF and MAF were most likely due to an ‘altered’ manner of speaking (i.e., an emphasis on phonation achieved via slowing down through extended syllable duration; Wingate 1976, Perkins 1979). Similarly others have espoused the notion that ‘the functional variable in regard to the reduction of stuttering is not DAF, but prolonged speech, and the latter can be produced without reliance on a DAF machine’ (Costello-Ingham 1993, p. 30). In fact, almost all behavioral stuttering therapies from the 1800s to the present day have used slow speech rate in some form as a therapeutic strategy (Van Riper 1973).

Kalinowski and colleagues have since refuted the notion that a slow rate of speech is a necessary antecedent for stuttering reduction while one who stutters speaks under AAF. In a series of papers they demonstrated that stuttering is reduced under conditions of AAF while speaking at a fast intelligible rate of speech (Kalinowski *et al.* 1993, 1996, Hargrave *et al.* 1994, MacLeod *et al.* 1995). Their results demonstrated reductions in stuttering rate between 70 and 90% regardless of speaking rate. This discovery contradicted the notion of the importance of slowed speech to fluency induced by AAF. That is, when syllable prolongation is eliminated, such as when speaking at a fast rate, the fluency enhancing properties of AAF are just as robust (i.e., a slowed speech rate is not a necessary antecedent for fluency improvement). It is reasonable, therefore, to speculate that the relevant variable(s) for fluency enhancement under conditions of AAF are related to auditory function. This shift necessitated a reexamination of the role of AAF in the reduction stuttering (Stuart and Kalinowski 1996).

At the same time, the stout findings of stuttering reduction with AAF were coupled with frustrating clinical observations. That is, those who stutter that were trained to reduce speech rate via specific articulatory/vocal targets did not always meet with clinical success. While speech may be more fluent following this traditional stuttering ‘motoric’ therapy approach, it was typically unnatural sounding (Runyan and Adams 1979, Martin *et al.* 1984, Metz *et al.* 1990, Runyan *et al.* 1990, Franken *et al.* 1992, Kalinowski *et al.* 1994) and not likely to be generalized from the therapy room to situations of daily living (e.g., Boberg 1981, Craig *et al.* 1996, Onslow *et al.* 1996). Put simply, relapse was frequent. The application of wearable prosthetic devices utilizing AAF as an adjunct or alternative to current stuttering therapy became apparent and was voiced repeatedly (Armson *et al.* 1995, Kalinowski *et al.* 1995, 1995, 1996, Hargrave *et al.* 1994, MacLeod *et al.* 1995, Stuart *et al.* 1996, 1997a, Armson and Stuart 1998).

The impetus behind the application of AAF in a prosthetic device for stuttering reduction was fivefold (Stuart *et al.* 2003): First, the reduction of stuttering under AAF is achieved virtually spontaneously with no conscious effort similar to that observed with choral or shadowed speech (Andrews *et al.* 1983, Armson *et al.* 1995). Second, AAF reduces stuttering in individuals with mild and severe stuttering without a sacrifice in perceived speech naturalness (White *et al.* 1995, Stuart *et al.* 2003). Third, stuttering reduction occurs during both the production of conversational speech and oral reading (Armson and Stuart 1998). Fourth, a significant reduction in stuttering rate can be achieved with monaural feedback regardless of ear relative to NAF (Stuart *et al.* 1997a). Finally, the robust effects of AAF occur outside the laboratory environment such as public speaking in front of various audience sizes (Armson *et al.* 1997) and speaking on the telephone to strangers (Zimmerman *et al.* 1997). It has also been recently reported that repeated exposure after three months exposure to DAF outside the clinical environment with minimal clinical guidance produces a carry-over effect and significant reductions in stuttering are observed in the absence of AAF (Van Borsel *et al.* 2003).

Prosthetic devices incorporating AAF have been available as a therapy alternative in the past. Unfortunately, however, devices have not been cosmetically appealing (i.e., inconspicuous self-contained at the ear-level). That is, technology has been limited to conspicuous devices that are body worn incorporating additional head worn pieces for signal delivery (Donovan 1971, Gruber 1971, Grant 1973, Pollock *et al.* 1976, Low and Lindsay 1979). Only recently was a self-contained ear-level device for application with those who stutter achieved (Stuart *et al.* 2003). The recently developed device incorporates a microdigital signal processor core that reproduces the high fidelity of unaided listening and auditory self-monitoring while at the same time delivering AAF. DAF and FAF signals in combination or isolation can be generated to the user in a cosmetically appealing custom in-the-canal (ITC) and completely in-the-canal (CIC) design. Programming of the device is achieved through a personal computer, interface, and fitting software.

The object of this paper was to examine the therapeutic application of the first self-contained ear-level device (Stuart *et al.* 2003) for those who stutter in three experiments. Previous research has been confined mostly to experiments conducted in laboratories and hence the need for investigation for the therapeutic application of devices was warranted. Specifically, in Experiment 1, the effect of a self-contained in-the-ear device delivering AAF was investigated with those who stutter during reading and monologue. The effect of custom made ITC and CIC devices on reading and monologue on stuttering rate was examined with adult and youth participants who stutter during initial fitting and at four months follow-up in Experiment 2. In Experiment 3, naïve listeners rated the speech naturalness of speech produced by the participants in Experiment 2 while reading and monologue without the device at the initial visit, reading and monologue with the device at the initial visit, and reading and monologue with the device at four months.

Experiment 1

Method

Participants

Two adolescent males, four adult males, and one adult female who stutter, (M = 21.9 years SD 7.3) participated in Experiment 1. Demographic information for individual participants is presented in table 1. The *Stuttering Severity Instrument for Children and Adults* (3rd ed.) (Riley, 1994) was employed to determine stuttering severity for each participant. None of the participants reported any speech or language disorders other than stuttering. All participants presented with developmental stuttering that was

Insert table 1 about here

exhibited at a rate of 5% stuttered syllables or higher in either reading or monologue tasks. All participants reported a history of therapy although none were enrolled at the time of testing. Participants presented with normal hearing sensitivity defined as having hearing thresholds of 25 dB HL or better at octave frequencies from 250 to 8000 Hz (American National Standards Institute 1996). Further, all participants presented with normal bilateral middle ear function (American Speech-Language-Association 1997). Participants were recruited at the Speech-Language & Hearing Clinic, Department of Communication Sciences and Disorders, East Carolina University, Greenville, North Carolina, USA. Informed consent was obtained from all the participants.

Apparatus

All testing was conducted in quiet therapy rooms. All speech samples were recorded with a video camera (Panasonic AG-188). A self-contained in-the-ear prosthetic fluency device was utilized. The device is described in detail elsewhere (Stuart *et al.* 2003) but briefly; the device incorporated a microdigital signal processor (DSP) device core (TOCCATA™, Dspfactory, Waterloo, ON). The chipset incorporated a 16-bit general-purpose software-programmable Harvard architecture DSP (RCore); a Weighted Overlap-Add (WOLA) filter bank coprocessor and a power-saving input/output controller for analysis filtering, gain application and synthesis filtering; and a low noise14-bit analog to digital (A/D) and a 14-bit digital to analog (D/A) converter for high fidelity sound production. The device housed an electret condenser microphone (Knowles TM4546) and a Class D amplified magnetic receiver (Knowles ES3207). Multiple channels, automatic gain control input, adaptive feedback suppression, dual time constants, microphone noise suppression, and a noise attenuation algorithm were utilized. The device implemented wide dynamic range compression without volume control. Devices were constructed with a 'stock' CIC ear shell (Audio D, Scarborough, ME). A Comply™ Snap Tip (Hearing Components, Inc., Oakdale, MN) was coupled to the shell for personalized fitting for all participants. Tip sizes were chosen to allow a comfortable tight occluded fit for all participants. The device components were manufactured by Micro-DSP (Chengdu, People's Republic of China).

Programming for device was established through a laptop personal computer (PC; IBM Think Pad 760ED; Intel Pentium 133 MHz, 16 MB RAM, and 2 GB hard drive) and hardware interface (AudioPro, Micro-DSP). The hardware interface allows communication between PC and the device. A serial RS-232C cable provided connection from the interface to the PC serial (COM) port. Linkage from the interface to the device was achieved with a standard CS44 programming 9-pole D-range male/female cable. The hardware interface and PC powered the device during linkage. A Microsoft® Windows® based operating system fitting software (SpeechEasy™ Fitting Software v1.2, Micro-DSP) was designed to work as a complete selection, fitting, and programming tool for device. The fitting software allowed access to system information, interface connection status, and fitting parameters. The fitting parameters included FAF (i.e., plus/minus shift to 2000 Hz in 500 Hz increments), DAF (i.e., 0-128 ms), linear gain control (i.e., four 5 dB step size increments), and independent eight band 20 dB gain controls (with center frequencies of 250, 750, 1250, 2000, 3000, 4000, 5250, and 7000 Hz). Spectral shifting that occurs during FAF can best be described as “frequency shifting”. With frequency shifting the frequencies of signal components are moved by a fixed frequency increment. The harmonic associations between signal components are not preserved. For example, signals of 500 Hz, 1000 Hz, and 2000 Hz shifted up by 500 Hz FAF result in signals of 1000 Hz, 1500 Hz, and 2500 Hz, respectfully (see Figure 6 from Stuart *et al.* 2003).

Procedure

Monaural device fittings were employed with all participants as no significant differences in stuttering rate for right versus left monaural conditions has been demonstrated (Stuart *et al.* 1997a). The test ear was randomly selected. The device settings were the same for all participants: FAF was set at 500 Hz up and combined with a DAF setting of 60 ms. These settings were based on optimal performances found in previous studies (MacLeod *et al.* 1995, Kalinowski *et al.* 1996, Stuart *et al.* 1996) and early clinical experience and success with these device settings. Linear gain and independent eight band gain controls were adjusted to preferred listening levels for all participants. Preferred listening levels were determined by asking each participant to produce the vowel /a/ for approximately 10 s and then counting to 20 at a normal rate and loudness with the device in place. Participants were instructed to listen to the altered signal generated by the device. Orientation with the device was approached from the standpoint that DAF and FAF are an emulation of choral speech and that a person’s own voice is required to initiate and maintain the second or choral signal. With this in mind, participants were instructed to make minor alterations to their speech production patterns with the intention of ‘highlighting’ the second signal to enhance the choral effect. Vowel prolongation and the use of ‘starters’ (e.g., ‘um’, ‘ah’, etc.) were taught for intermittent use to help initiate or maintain the second choral-like signal. However, participants were specifically instructed to make modifications only when necessary and to speak using their usual loudness, rate, and intonation patterns.

Each participant in Experiment 1 read different 300 syllable passages extracted from junior high texts in social studies and science. Passages had similar theme and syntactic complexity. Participants produced 300 syllables of monologue speech. Both speech tasks were produced with and without a device. Reading and monologue conditions were counter balanced. In all segments of Experiment 1, one other person, either a research assistant or one of the experimenters, who served as a listener, accompanied the participant in the therapy room. Most participants talked continuously throughout each monologue condition, typically several minutes to insure that 300 syllables were produced. In some instances the listener occasionally used brief prompts to ensure monologue output was maintained (after Armson and Stuart 1998). Participants produced speech without the device in the control condition first in an effort to eliminate any possible carry-over fluency effects of the device. The device remained interfaced with the PC during the experimental condition. Participants were instructed to read at their normal rate with normal vocal intensity under both conditions. For all conditions participants were instructed not to use any previously used or taught therapeutic strategies or techniques to control or reduce stuttering.

A trained research assistant analyzed the speech samples from the video recordings. The first 300 syllables produced by the participants were analyzed for each condition. Stuttered syllables were counted for each condition. A stuttered syllable was defined as a part-word prolongation, part-word repetition, or inaudible postural fixation (i.e., silent block). The same research assistant recalculated stuttered syllables for 15% of the speech samples chosen at random. Intrajudge syllable-by-syllable agreement was 0.94, as indexed by Cohen's *kappa* (Cohen 1960). A second research assistant independently determined stuttered syllables for 15 % of the speech samples chosen at random. Interjudge syllable-by-syllable agreement, was 0.92 as indexed by Cohen's *kappa*. Cohen's *kappa* values above 0.75 represent excellent agreement beyond chance (Fleiss 1981).

Results

Means and standard errors for proportion of stuttered syllables per 300 syllables (i.e., number of stuttered syllables/300 syllables) as a function of device (i.e., present vs. absent) and speech task (i.e., reading vs. monologue) are shown in figure 1.

Insert figure 1 about here

A two-factor analysis of variance with repeated measures was performed to investigate the effect of speech task and device on the proportion of stuttered syllables. The participants' proportional scores were transformed to arcsine units prior to subjecting them to inferential statistical analysis. A statistically significant main effect of device was found [F (1,6) = 13.2, Huynh-Felt p = 0.011, η^2 = 0.69]. No significant main effect of task

[*F* (1,6) = 0.63, Huynh-Felt $p = 0.46$, $\eta^2 = 0.095$, $\phi = 0.10$] or a device by task interaction was evident [*F* (1,6) = 2.60, Huynh-Felt $p = 0.16$, $\eta^2 = 0.30$, $\phi = 0.28$]. In other words, the proportion of stuttered syllables was significantly reduced with the device in place regardless of reading or monologue.

Discussion

Stuttering events were significantly reduced with persons who stutter while experiencing AAF via an in-the-ear device. The proportion of stuttered syllables was reduced by approximately 90% during reading and 67% during monologue. These reductions in stuttering rate are consistent with previous reports of robust responses to DAF and FAF and the combinations thereof with signal delivery via other auditory feedback means achieved electronically (Howell *et al.* 1987, Kalinowski *et al.* 1993, 1996,1999, Hargrave *et al.* 1994, MacLeod *et al.* 1995, Stuart *et al.* 1996, 1997a, Armson and Stuart 1998).

In addition, consistent with earlier investigations, reduction of stuttering occurred with monaural feedback (Stuart *et al.* 1997a). There was a much more robust effect observed here during monologue speech than previously reported (Ingham *et al.* 1997, Armson and Stuart 1998).

Experiment 2

Method

Participants

Eight individuals with developmental stuttering participated in Experiment 2. Four participants were adults (*M* = 38.0 years *SD* 15.9) and four were youth (i.e., one child and three adolescents; *M* = 12.5 years *SD* 2.6). None of those enrolled in Experiment 1 described above participated in Experiment 2. Participants met the same criteria as those in Experiment 1. Additionally, they were required to be willing to return for multiple follow-up recordings over the one-year period and agree to wear the prosthetic fluency device for at least five hours per day. Participants were recruited at the Speech-Language & Hearing Clinic, Department of Communication Sciences and Disorders, East Carolina University, Greenville, North Carolina, USA. The first four adults and youth (and guardians) who fit the selection criteria and agreed to the above terms were enrolled in this experiment. All participants (or their guardians for them) reported a history of therapy although none were enrolled at the time of testing. Informed consent was obtained from all the participants. Participants' demographic information is presented in table 1. Again, for each participant, the *Stuttering Severity Instrument for Children and Adults* (3rd ed.) (Riley, 1994) indexed stuttering severity. Each participant (or their caregiver) was required to make a $500 US refundable deposit for the safe keeping of the device and was offered the option to purchase the device after the one-year period for cost.

Apparatus

The apparatus employed in Experiment 2 were the same as that in Experiment 1 with one exception: Personal ear-level devices were constructed in either ITC or CIC custom made shell designs. The shells were fabricated from individual ear mold impressions. Audio D (Scarborough, ME) constructed the shells that housed the device components with a standard light-curable acrylic shell mold material (Audalite™). Faceplates with the device components were provided by Micro-DSP (Chengdu, People's Republic of China). The youth in the experiment received ITC devices while the adults received CIC devices. The ITC devices were necessary due to small ear canal volumes that could not accommodate the CIC design.

The ITC and CIC devices were similar in design as described in Experiment 1 with the following exceptions: Knowles TM4546 and Knowles EM4346 electret condenser microphones were incorporated in the CIC and ITC model, respectively. The ITC model included a volume control while the CIC model implemented wide dynamic range compression without volume control. Size 312 and 10 zinc-air batteries powered the ITC and CIC model, respectively.

Procedure

Participants received a standard clinical workup during their initial clinical assessment. Following enrollment in the experiment, participants had an ear mold impression taken by an audiologist certified by the American Speech-Language Hearing Association for the device construction. Each participant determined the choice of ear to be fit with the device. Three participants opted for left ear devices while five participants chose the right ear. Monaural device fittings were employed with all participants. Participants returned typically within three weeks to receive their customized device and undergo fitting and orientation (as described in Experiment 1 above). During that time, participants (and guardians in the cases of the youth) were also provided with general information regarding the care and maintenance of the device. The orientation session required between 45 and 90 minutes.

The same testing with instruction as described in Experiment 1 followed fitting and orientation: participants read 300 syllable passages and produced 300 syllables of monologue speech with and without a device. Conditions were counter balanced.

Participants produced speech without the device in the control condition first to prevent any possible carry-over fluency effects of the device. The device settings were the same for all participants: FAF was set at 500 Hz up and combined with a DAF setting of 60 ms. The device was not interfaced with the PC during the experimental condition as the settings were programmed and written to the chipset during fitting.

Following the fitting and testing, researchers and or assistants contacted each participant and/or guardian via telephone and/or electronic mail to confer that the device was operating and participant compliance was maintained. The adults on average reported eight hours of daily use. The youth reported slightly less on average daily use (i.e., four to six hours) typically because of their more active lifestyles. Every participant returned to the clinic, either once or twice for a follow-up session in order to assess that the device gain set to their preferred listening level during the initial session was still appropriate for different speaking environments encountered in their situations of daily living. These sessions typically lasted for approximately 30 to 45 minutes.

At four months post fitting (plus/minus one week), participants returned to the clinic for follow-up testing. Participants again read different 300 syllable passages and produced 300 syllables of monologue speech with and without a device. Reading and monologue conditions were counter balanced. Test conditions and instruction were the same as during the initial assessment.

In all, each participant produced eight samples of speech (i.e., four from the initial assessment and four from the assessment at four months). A count of stuttered syllables was determined from the video recordings for all participants for each condition by a trained research assistant. The same definition of stuttering used in

Experiment 1 was employed. The first 300 syllables produced by the participants were analyzed for each condition. The research assistant and a second research assistant recalculated the number of stuttered syllables for 50% of the speech samples chosen at random. Interjudge syllable-by-syllable agreement, as indexed by Cohen's *kappa* was 0.84 while intrajudge Cohen's *kappa* syllable-by-syllable agreement was 0.91 (Cohen 1960).

Results

Means and standard errors for proportion of stuttered syllables per 300 syllables (i.e., number of stuttered syllables /300 syllables) as a function of group (i.e., youth vs. adult), time (i.e., initial vs. four months), speech task (i.e., reading vs. monologue), and device (i.e., present vs. absent) are illustrated in figure 2. A four-factor mixed analysis of

Insert figure 2 and table 2 about here

variance was performed to investigate differences in mean proportions of stuttering events as a function of group, time, speech task, and device. The participants' proportional scores were transformed to arcsine units prior to subjecting them to inferential statistical analysis. The summary of the analysis is presented in table 2. As evident in table 2, only a significant main effect of device was found ($p = 0.0028$). All other main effects and interactions were not significant ($p > 0.05$).

Discussion

These findings indicate the proportion of stuttering events was significantly reduced with the device in place regardless of speech task or group and remained so after four months of time. Collapsed across speech task, time, and group an approximately 81 % reduction in the proportion of stuttered syllables occurred with the device in place compared to not in place. As in Experiment 1, there was no significant difference between reading and monologue in the proportion of stuttered syllables observed.

Van Borsel *et al.* (2003) reported a carry-over effect following repeated daily exposure to DAF over a three month period. Prior to repeated exposure of DAF, nine participants displayed significantly more stuttering on five speech tasks (i.e., automatic speech, conversation, picture description, reading aloud, and repeating words and sentences) during NAF compared to DAF. After an average of 260 minutes of repeated exposure over three months, the percentage of stuttered words during NAF was not significantly different from DAF on all tasks except repeating words and sentences. The percentage of stuttered words was significantly lower during NAF following repeated exposure of DAF than before on all speech tasks except conversation. In other words, carry-over was evident during NAF following repeated exposure to DAF. This carry-over effect was not evident in this experiment following four months of use with the in-the-ear device. Participants displayed significantly more stuttering without the device regardless of initial fitting or four months later. The reason for these discrepant results is unknown.

Experiment 3

Method

Participants

Fifteen naïve young adult undergraduate students attending East Carolina University, Greenville, NC participated in Experiment 3 (*M* = 23.1 years *SD* 4.0; 4 males and 11 females). Criteria for participation in the experiment included a negative history of speech, language, or hearing pathology and no clinical or academic training in speech-language pathology.

Apparatus

Twelve speech samples were extracted from the video recordings of each participant in Experiment 2. Two separate 15 s audio segments of uninterrupted speech were randomly selected from each participant's speech production under the following six conditions in Experiment 2: reading and monologue without the device at initial visit, reading and monologue with the device at initial visit, and reading and monologue with the device at four months. The 15 s audio samples were extracted from the videotapes with a PC (Gateway 600 YGR; Intel Pentium 4 1.8 GHz, 512 MB RAM, and 40 GB hard drive). Samples were input via a Sound Blaster Live! CT4870 audio board with MediaStudio Pro 6.0VE Video Capture software. None of the tracks were subjected to any sound editing. Final editing was done with an Apple Computer, Inc. Power Mac G4 PC (733 MHz Power PC, 256 MB RAM, and 60 GB hard drive) with BIAS, Inc. Peak 2.5 DV Digital Audio Editing Software. Each tract was imported to Adobe Premiere 6.0 and formatted to include in series a synthetic marker of the word "sample" followed by the respective track number, a 500 ms silence, the 15 s track, and 4 s silence. Fifteen s samples were chosen to reduce test time and have been found to provide similarly reliable measures of speech naturalness as longer samples (Onslow *et al.* 1992). Twelve digital audio tracks were created for each participant resulting in a total of 96 tracks from the eight participants in Experiment 2. The 96-track order was randomized (using http://www.randomizer.org) and coded accordingly. The 96 tracks were then recorded onto a compact disk (CD) via Apple Computer, Inc. iTunes 1.0.1.

Procedure

Speech naturalness ratings took place in a classroom setting and followed the same procedure described by Kalinowski *et al.* (1994). Speech samples were routed from a compact disk deck (JVC XL-FZ258) to two speakers (Bose Video Roommate Powered Speaker System) mounted on tripods at a height of approximately two meters at the front of the classroom. Speech samples were delivered at a comfortable listening level (i.e., approximately 65 dB SPL).

Prior to the start of testing, participants were provided with an informed consent form, verbal instructions, and two response sheets. The response sheets contained a nine-point rating scale for assessing the speech naturalness (Martin *et al.* 1984) for 48 speech samples. Participants were asked to rate each speech sample without being provided an operational definition of speech naturalness. The listeners rated each track for naturalness in which ‘1’ was ‘highly natural’ and ‘9’ was ‘highly unnatural’. Verbal instructions were identical to that used by Martin *et al*. A five-minute rest period was provided at the end of 48 tracks.

Results

A Spearman rank-order correlation coefficient was undertaken to investigate intrarater reliability prior to inferential analysis. A statistically significant positive correlation ($r_s = 0.78$) was found between the ratings of samples one and two ($p <$ 0.0001). Considering the good intrarater reliability rating, ratings of samples one and two were averaged to result in 48 ratings from each rater. An intraclass correlation (2,1)

(Shrout and Fleiss 1979) was calculated to assess interrater reliability for the combined average ratings. The intraclass correlation was 0.73, a value considered next to excellent reliability (Fleiss 1986). Finally, listener's ratings for the four adult and youth speakers' speech samples were averaged to give mean rating values as a function of group (i.e., youth vs. adult) and speech task (i.e., reading vs. monologue), and speaking conditions (i.e., initial fitting without device vs. initial fitting with device vs. four months with device). This rendered from each participant's 48 ratings 12 average ratings (i.e., two groups by two speech tasks by three speaking condition). These mean naturalness ratings as a function of group, speech task, and speaking conditions are shown in figure 3.

Insert figure 3 about here

Four sets of planned *a priori* orthogonal single-*df* contrasts (Keppel and Zedeck 1989, Keppel 1991) were performed to evaluate the differences in mean naturalness ratings for each reading and monologue conditions for the adult and youth samples. A summary of those comparisons is presented in table 3. In all four sets of contrasts, it

Insert table 3 about here

was found that mean naturalness ratings of speech samples generated with the device were judged to be more natural sounding than those without the device ($p < 0.0001$). There was no significant difference between the mean naturalness ratings of speech samples generated during the initial fitting with the device relative to that at four months with the device ($p > 0.05$) in all cases except with the youth while engaged in monologue. For that condition, raters judged the speech produced at the initial fitting as more natural.

Discussion

Naïve listeners rated the speech samples produced by those who stutter while wearing the device significantly more natural sounding than those produced without the device. This was true for both adult and youth, reading and monologue, and during initial fitting and at post fitting follow-up. Put simply, the perceived naturalness of speech samples from people who stutter was significantly improved with the device and remained so over time. These findings are consistent, at least for first exposure in that AAF reduces stuttering without a sacrifice in perceived speech naturalness (White *et al.* 1995, Stuart *et al.* 2003). This is in contrast to Ingham *et al.* (1997) who reported equivocal findings with speech naturalness ratings of oral reading and spontaneous speech. Of four individuals who stutter, perceptions of speech naturalness of their speech production were found not to change with one participant, worsen in another participant, and improve with the remaining two participants relative to speech produced in during NAF.

It should be noted that although the speech naturalness of those who stutter was rated as more natural during DAF relative to NAF, it was not rated as natural as that reported for fluent speakers. That is, fluent speakers are typically rated on average one to three on the naturalness rating scale (Martin *et al.* 1984, Ingham *et al.* 1985, Runyan *et al.* 1990, Stuart *et al.* 2003). It was rated more natural, however, than the post-therapeutic speech of those following traditional motoric therapies (Franken *et al.* 1992, Kalinowski *et al.* 1994, Stuart *et al.* 2003).

General Discussion

The findings of these experiments are threefold: First, it was demonstrated in Experiment 1 that an in-the-ear device electronically delivering AAF effectively reduced stuttering. This was no surprise. Originally, the intent with signal delivery of AAF was to provide a speech level output to one who stutters that is consistent with auditory self - monitoring during their normal conversation (Kalinowski *et al.* 1993). That is, signal intensity should approximate real ear average conversation sound pressure levels of speech outputs from a normal hearing speaker. No matter what transducer or means of signal delivery, if this is achieved *in situ* at the tympanic membrane stuttering should be reduced. Evidence of this in the present experiments was revealed by similar reductions in stuttering relative to previous reports of the robust effects of DAF and FAF (Howell *et al.* 1987, Kalinowski *et al.* 1993, 1996, Hargrave *et al.* 1994, MacLeod *et al.* 1995, Stuart *et al.* 1996). Second, this is the first report of a reduction in the proportion of stuttered syllables evidenced with the device in place during reading and monologue for adults and youth at fitting and four months post follow-up. Finally, naïve listeners rated the speech produced by those who stutter while wearing the device significantly more natural sounding than without the device. Again this was constant for adults and youth while reading and with monologue. This finding is consistent with previous reports of speech produced under FAF: White *et al.* (1995) reported clinicians evaluated speech produced by those who stutter under FAF as significantly more natural-sounding than their speech under nonaltered auditory feedback. In addition, time series data reported by Ingham *et al.* (1997) show that improved speech naturalness was associated with reduced stuttering under FAF for two of four adults who stutter (i.e., participants A. G. and E.O.). Stuart *et al.* (2003) also reported that speech samples produced under DAF and FAF were rated as significantly more natural sounding than NAF for both those with mild and severe stuttering. In all, these findings support the notion that a self-contained in-the-ear device delivering AAF is a viable tool for the amelioration of stuttering based on the fact that similar levels of reduction in stuttering observed at the time of initial fitting were maintained four months later and the speech produced while wearing the device is perceived as more natural than without the device.

These experiments, however, were not without their limitations. First, although participants in Experiments 1 and 2 displayed significant reductions in stuttering not all individuals respond favourably or at all to AAF. We have reported in previous studies (Kalinowski *et al.* 1993, 1996,1999, Hargrave *et al.* 1994, MacLeod *et al.* 1995, Stuart *et al.* 1996, 1997a, Armson and Stuart 1998) varying levels of stuttering reduction under electronically generated AAF conditions. Equivocal findings have been reported for the benefit or lack thereof with AAF during conversational speech. Ingham *et al.* (1997) reported two of four participants did not display stuttering reduction under FAF with shifts of plus/minus one octave during reading and spontaneous speech. Armson and Stuart (1998) reported that 10 of 12 participants showed no reduction in stuttering rate during a monologue task with either a plus or minus one octave shift in FAF. In addition, as noted above, equivocal findings with speech naturalness ratings were also reported by Ingham *et al.*: Perceptions of speech naturalness of their speech production improved with only two participants relative to speech produced during NAF and worsened in another participant. It would be reasonable to accept that not all people who stutter would benefit from an in-the-ear device that delivers AAF in terms of stuttering reduction and speech naturalness. Second, this study did not assess stuttering reduction in situations of daily living, particularly in situations that supposedly impose communicative stress and exacerbate stuttering. However, there is evidence that AAF reduces stuttering outside the laboratory environment such as in the presence of multiple listeners (Armson *et al.* 1997) and utilizing a telephone with strangers (Zimmerman *et al.* 1997). One could reasonably expect that in-the-ear devices delivering AAF could provide the same results in terms of stuttering reduction. Third, measures of disability and handicap experienced by the participants following the use of the in-the-ear devices were not evaluated. For example, Van Borsel *et al.* (2003) reported that despite observed reductions in stuttering following treatment of repeated exposure to DAF, one of nine participants did not report a perceived improvement in fluency or emotional state. One could also reasonably expect that not all persons who stutter would perceive a reduction in disability and/or handicap following the use of an in-the-ear device delivering AAF. Finally, one does not know the benefit of long-term use of these devices. There is previous research, however, that suggests a wearable, albeit not ear level device, delivering altered auditory feedback can maintain long-term reduction of stuttering (Dewar *et al.* 1979). The “Edinburgh masker” was reported to be effective in reducing stuttering in 89% of 195 persons who stutter. In a follow-up of 62 of these persons, 82% were found to have benefit with six months use and some up to three years later. There is some preliminary evidence from a single case study that supports success for the present device following more than 100 hours of use

(Kalinowski 2002). Clearly, further investigation is warranted to address all of these limitations.

An important implication of these findings is that therapeutic intervention does not have to imprint a perceptual "therapeutic signature" which immediately identifies a speaker as different from all other speakers. There are two types of therapeutic signature that one can identify: The first signature is motoric is nature. Self-imposed motoric alterations are core to some therapy programs whereby participants are trained to produce prolonged speech (for a review see Bloodstein 1995). Prolonged speech requires careful and deliberate attention to the mechanics of speech production. Speech production following therapy, although generally forward flowing, is inherently unnatural and laborious (Runyan and Adams 1979, Martin *et al.* 1984, Metz *et al.* 1990, Runyan *et al.* 1990, Franken *et al.* 1992, Kalinowski *et al.* 1994). Programs for stuttering have attempted to integrate the goal of attaining naturalness aspects into their motoric behavioral training but results have been less than robust and generalization as always in stuttering was questioned (Boberg 1981, Craig *et al.* 1996, Onslow *et al.* 1996). The results in this study are seminal in that naturalness was not taught. Participants were just told to speak and their end result was perceived as more natural; that naturalness was derived from speech produced via a prosthetic device and not some ingrained behavioral technique. Simply put, there was no motoric therapeutic signature because the therapeutic modality was a signal delivery system that exploited AAF. One may have suspected that a therapeutic signature would have, in fact, been present with the speech production of the participants in this study. Recall, that participants were instructed to make minor alterations to their speech production patterns with the intention of highlighting the second signal to enhance the choral effect from the device. It was advised that these motoric strategies be employed during periods of silence and/or anticipated moments of stuttering when the AAF could not be generated due to the absence of an input signal. These strategies were intermittent. The naturalness ratings from the participants in this study suggest that speech modifications were minimal if at all.

Another therapeutic signature specific to device-based therapies that deliver signals to reduce stuttering is their cosmetic appeal or lack thereof (Stuart *et al.* 2003). In the past, technology restricted prosthetic devices to be notoriously, conspicuous body worn, incorporating additional head worn pieces for signal delivery (Donovan 1971, Gruber 1971, Grant 1973, Pollock *et al.* 1976, Low and Lindsay 1979). These devices, although often effective at various levels depending on quality control of the manufacturer, architecture, and signal delivery system, often failed to be embraced by those who stutter because their physical dimensions brought immediate and additional unwanted attention. That is, people who stutter would rather remain silent or stutter than immediately be identified as different. Although technology is improving and devices shrink in size, those available presently remain “desktop systems” or if worn at the ear level do so behind the ear and require additional transmitters for signal processing (e.g., Jabra® FreeSpeak™ and Pocket Fluency System® by Casa Futura Technologies, Bolder, CO) and/or transducers for signal input or (e.g., Fluency Master, National Association for Speech Fluency, New Hyde Park, NY). Newer technology recently developed (Stuart *et al.* 2003) and utilized in these experiments does not come with a concomitant therapeutic signature: The device is cosmetically appealing because of its inconspicuous design and speech produced by people who stutter is perceived to be more natural than without the device.

Another important observation in these studies was that stuttering was significantly reduced during monologue with AAF. In fact, there was no significant difference between the proportion of stuttered syllables for reading and monologue. This is in contrast to what was previously reported by Ingham *et al*. (1997) who found only two of four and Armson and Stuart (1998) who found two of 12 participants responded favourably to FAF during monologue. Three possible explanations are offered. First, it may be that some AAF conditions are more optimal than others for monologue/spontaneous speech. Ingham *et al.* employed FAF alterations of plus or minus one octave while Armson and Stuart utilized plus or minus one-quarter octave shifts. The participants in these studies were exposed to a frequency shift of plus 500 Hz in concert with DAF of 60 ms. Second, the participants were given different directives in these studies. They were instructed to attend to the second speech signal generated by the device and to make intermittent minor alterations to their speech production patterns with the intention of highlighting the second signal to enhance the choral effect from the device. This was not the case in the previous studies. Participants were simply informed that in some conditions their vocal feedback was going to be altered in some manner. It is difficult to gauge whether either of these directives had a significant effect on reducing stuttering. In the first case, while instructed to attend, participants did not show a greater reduction in stuttering herein during reading compared to previous reports were no such instruction was given (Kalinowski *et al.* 1993, 1996, Hargrave *et al.* 1994, MacLeod, *et al.* 1995, Stuart *et al.* 1996, 1997a, Armson and Stuart 1998). Further, it is unlikely that instruction to use some prolongations was responsible for reduction of stuttering as noted above naturalness ratings of speech production from participants in these experiments suggest that speech modifications were minimal, if at all. It may simply reflect that fact that there remains a differential effect among those who stutter to AAF and the differences among these studies reflect different samplings of the population.

In conclusion, it is suggested that the findings of this paper introduce a new treatment modality for stuttering. With this treatment, signal delivery via an inconspicuous, all in the ear device to reduce stuttering is the primary source of fluency generation. Unlike most previous treatment modalities, treatment orientation is brief with a three-hour fitting follow-up. This treatment also differs with an *a priori* goal to eliminate the visual, acoustic, and perceptual signatures that identify the person who stutters as immediately being different. In summary, the prosthetic device reduces stuttering significantly, it is cosmetically appealing, and speech produced by the wearer is perceived as more natural than without the device in place. These findings illustrate that simply placing a device in a person's ear; offering good therapeutic instructions for a brief time; and keeping in contact with that person to maintain care of the device, answer questions, and give further instructions, one was able to provide efficient and effective reduction in stuttering at initial fitting and four months post-fitting. Suggesting new technology as a therapeutic alternative is not new. Silverman (1997) has advocated the use of alternative technologies as viable communication aids for people who stutter. We agree and wholeheartedly support Silverman's contention that "*we have an ethical* *responsibility to make our clients aware*…. *It is up to them whether they want to use it* [italics added]” (p. 64).

References

ADAMCZYK, B., KUNISZYK-JOZKOWIAK, W., and SMOLKA, E., 1979, Influence of echo and reverberation on the speech process. Folia Phoniatrica, 31, 70-81.

ADAMCZYK, B., SADOWSKA, E., and KUNISZYK-JOZKOWIAK, W. 1975, Influence of reverberation on stuttering. Folia Phoniatrica, 27, 70-81.

AMERICAN NATIONAL STANDARDS INSTITUTE 1996, Specifications For Audiometers (ANSI S3.6-1996), (New York: American National Standards Institute).

AMERICAN-SPEECH-LANGUAGE-HEARING ASSOCIATION, 1997, Guidelines For Audiologic Screening, (Rockville Pike, MD: American-Speech-Language-Hearing Association).

ANDREWS, G., CRAIG, A., FEYER, A., HODDINOT, S., HOWIE, P., and NEILSON, M., 1983, Stuttering: A review of research findings and theories circa 1982. Journal of Speech and Hearing Disorders, 48, 226-246.

ARMSON, J. and STUART, A., 1998, Effect of extended exposure to frequency altered feedback on stuttering during reading and spontaneous speech. Journal of Speech, Language, and Hearing Research, 41, 479-490.

ARMSON, J., FOOTE, S., WITT, C., KALINOWSKI, J., and STUART, A., 1997, Effect of frequency altered feedback and audience size on stuttering. European Journal of Disorders of Communication, 32, 359-366.

ARMSON, J., KALINOWSKI, J., and STUART, A., 1995, A model of stuttering remediation: Multiple factors underlying fluency enhancement. In C.W. Starkweather and H.F.M. Peters (Eds.) Stuttering: Proceedings from the First World Congress on

Fluency Disorders (Nijmegen, The Netherlands: University Press Nijmegen), pp. 296-300.

BLOODSTEIN, O., 1995, A handbook on stuttering (5th ed.), (San Diego: Singular).

BOBERG, E., 1981, Maintenance of Fluency, (New York: Elsevier North Holland).

BORDEN, G .J., 1979, An interpretation of research on feedback interruption in speech. Brain and Language, 7, 307-319.

CHASE, R.A., SUTTON, S., and RAPIN, I., 1961, Sensory feedback influences on motor performance. Journal of Auditory Research, 1, 212-223.

CHERRY, E. and SAYERS, B., 1956, Experiments upon total inhibition of stammering by external control and some clinical results. Journal of Psychomotor Research, 1, 233-246.

COHEN, J., 1960, A coefficient of agreement for nominal scales. Educational and Psychological Measurement, 20, 37-46.

COSTELLO-INGHAM, J.C., 1993, Current status of stuttering and behavior modification-I: Recent trends in the application of behavior modification in children and adults. Journal of Fluency Disorders, 18, 27-55.

CRAIG, A., HANCOCK, K., CHANG, E., MCCREADY, C., SHEPLEY, A., MCCAUL, A., COSTELLO, D., HARDING, S., KEHREN, R., MASEL, C., and REILLY, K., 1996. A controlled clinical trial for stuttering in persons aged 9 to 14 years. Journal of Speech and Hearing Research, 39, 808-826.

DEWAR, A., DEWAR, A.D., AUSTIN, W.T.S., and BRASH, H.M., 1979, The long term use of an automatically triggered auditory feedback masking device in the treatment of stuttering. British Journal of Disorders of Communication, 14, 219-229.

DONOVAN, G.E., 1971, A new device for the treatment of stammering. British Journal of Disorders of Communication, 6, 86-88.

FLEISS, J.L., 1981, Statistical Methods for Rates and Proportions (2nd ed.), (New York: John Wiley and Sons).

FLEISS, J.L., 1986, The Design And Analysis Of Clinical Experiments, (New York: John Wiley and Sons).

FRANKEN, M.C., BOVES, L., PETERS, H.F.M., and WEBSTER, R., 1992, Perceptual evaluation of the speech before and after fluency shaping therapy. Journal of Fluency Disorders, 17, 223-242.

GRANT, G.C., 1973, A portable delayed auditory feedback (DAF) unit for stutterers. Biomedical Engineering, 8, 345-346,

GRUBER, L., 1971, The use of the portable voice masker in stuttering therapy. Journal of Speech and Hearing Disorders, 36, 287-289.

HARGRAVE, S., KALINOWSKI, J., STUART, A., J., ARMSON, and JONES, K., 1994, Effect of frequency-altered feedback on stuttering frequency at normal and fast speech rates. Journal of Speech and Hearing Research, 37, 1313-1319.

HOWELL, P., EL-YANIV, N., and POWELL, D. J., 1987, Factors affecting fluency in stutterers, In H. F. M. Peters and W. Hulstijin (Eds.) Speech Motor Dynamics In Stuttering (New York: Springer-Verlag), pp. 361-369.

INGHAM, R.J., GOW, M., and COSTELLO, J.M., 1985, Stuttering and speech naturalness: some additional data. Journal of Speech & Hearing Disorders, 50, 217-219.

INGHAM, R.J., MOGLIA, R.A., FRANK, P., COSTELLO-INGHAM, J., and CORDES, A., 1997, Experimental investigation of the effects of frequency altered feedback on the speech of adults who stutter. Journal of Speech, Language and Hearing Research, 40, 361-372.

KALINOWSKI, J., 2003, Self-reported efficacy of an all in-the-ear-canal prosthetic device to inhibit stuttering during one hundred hours of university teaching: A case study. Disability and rehabilitation, 25, 107-111.

KALINOWSKI, J., ARMSON, J., ROLAND-MIESZKOWSKI, M., STUART, A., and GRACCO, V. L., 1993, Effects of alterations in auditory feedback and speech rate on stuttering frequency. Language and Speech, 36, 1-16.

KALINOWSKI, J., ARMSON, J., STUART, A., HARGRAVE, S., SARK, S., and MACLEOD, J., 1995, Effect of alterations in auditory feedback on stuttering frequency during fast and normal speech rates. In C.W. Starkweather and H.F.M. Peters (Eds.) Stuttering: Proceedings from the First World Congress on Fluency Disorders (Nijmegen, The Netherlands: University Press Nijmegen), pp. 51-55.

KALINOWSKI, J., NOBLE, S., ARMSON, J., and STUART, A., 1994, Naturalness ratings of the pretreatment and posttreatment speech of adults with mild and severe stuttering. American Journal of Speech-Language Pathology, 3, 65-70.

KALINOWSKI, J., STUART, A., SARK S., and ARMSON, J., 1996, Stuttering amelioration at various auditory delays and speech rates. European Journal of Disorders of Communication, 31, 259-269.

KALINOWSKI, J., STUART, A., WAMSLEY, L., and RASTATTER, M.P., 1999, Effect of monitoring condition and altered auditory feedback on stuttering frequency. Journal of Speech, Language, and Hearing Research, 42, 1347-1354.

KEPPEL, G., 1991, Design and Analysis: A Researcher's Handbook (3rd ed.), (Englewood Cliffs, NJ: Prentice Hall).

KEPPEL, G. and ZEDECK, S., 1989, Data Analysis for Research Design, (New York: W.H. Freeman and Company).

LOW, J.M. and LINDSAY, D.D., 1979, A body-worn delayed auditory feedback fluency aid for stammerers. Journal of Biomedical Engineering, 1, 235-239.

MARAIST, J.A. and HUTTON, C., 1957, Effects of auditory masking upon speech of stutterers. Journal of Speech and Hearing Disorders, 22, 385-389.

MARTIN, R.R., HAROLDSON, S.K., and TRIDEN, K.A., 1984, Stuttering and speech naturalness. Journal of Speech and Hearing Disorders, 49, 53-58.

MACLEOD, J., KALINOWSKI, J., STUART, A., and ARMSON, J., 1995, Effect of single and combined altered auditory feedback on stuttering frequency at two speech rates. Journal of Communication Disorders, 28, 217-228.

METZ, D.E., SCHIAVETTI, N., and SACCO, P.R., 1990, Acoustic and psychophysical dimensions of the perceived speech naturalness of nonstutterers and posttreatment stutterers. Journal of Speech and Hearing Disorders, 55, 516-525.

MYSAK, E.D., 1966, Speech Pathology: Feedback Theory, (Springfield, IL: Charles C. Thomas).

NAYLOR, R.V., 1953, A comparative study of methods of estimating the severity of stuttering. Journal of Speech and Hearing Disorders, 18, 30-37.

ONSLOW, M., ADAMS, R., and INGHAM, R., 1992, Reliability of speech naturalness ratings of stuttered speech during treatment. Journal of Speech and Hearing Research, 35, 994-1001.

ONSLOW, M., COSTA, L., ANDREWS, C., HARRISON, E., and PACKMAN A., 1996. Speech outcomes of a prolonged-speech treatment for stuttering. Journal of Speech and Hearing Research, 39, 734-49.

PERKINS, W. H., 1979, From psychoanalysis to discoordination. In H.H. Gregory (Ed.) Controversies About Stuttering Therapy (Baltimore: University Park Press), pp. 97-127.

POLLOCK, R., GREGORY, N.L, and SHAW, A., 1976, A solid state delayed auditory feedback system for speech therapy. Biomedical Engineering, 11, 413-414.

RILEY, G.D., 1994, Stuttering Severity Instrument for Children and Adults (3rd ed.), (Austin, TX: Pro-Ed).

RUNYAN, C. and ADAMS, M.R., 1979, Unsophisticated judges' perceptual evaluations of the speech of 'successfully treated' stutterers. Journal of Fluency Disorders, 4, 29-48.

RUNYAN, C.M., BELL, J.N., and PROSEK, R.A., 1990, Speech naturalness ratings of treated stutterers. Journal of Speech and Hearing Disorders, 55, 434-438.

SHANE, M.L.S., 1955, Effect on stuttering of alteration in auditory feedback. In W. Johnson and R.R. Luetenegger (Eds.) Stuttering in Children and Adults: Thirty Years of Research at the University of Iowa (Minneapolis, MN: University of Minnesota), pp. 286-297.

SHROUT P.E. and FLEISS J.L., 1979, Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin, 86, 420-428.

SILVERMAN, F.H., 1997, Telecommunication relay services: An option for stutterers. Journal of Fluency Disorders, 22, 63-64.

SMOLKA, E. and ADAMCZYK, B., 1992, Influence of visual echo and visual reverberation on speech fluency of stutterers. International Journal of Rehabilitation Research, 15, 134-139.

STUART, A. and KALINOWSKI, J., 1996, Fluent speech, fast articulatory rate, and delayed auditory feedback: Creating a crisis for a scientific revolution? Perceptual and Motor Skills, 82, 211-218.

STUART, A., KALINOWSKI, J., ARMSON, J., STENSTROM, R., and JONES, K., 1996, Fluency effect of frequency alterations of plus/minus one-half and one-quarter octave shifts in auditory feedback of people who stutter. Journal of Speech and Hearing Research, 39, 396-401.

STUART, A., KALINOWSKI, J., and RASTATTER, M.P., 1997a, Effects of monaural and binaural altered auditory feedback on stuttering frequency. The Journal of the Acoustical Society of America, 101, 3806-3809.

STUART, A., KALINOWSKI, J., and RASTATTER, M.P., 2003, The effect of altered auditory feedback on the perception of speech naturalness in people who stutter. (In preparation).

STUART, A., KALINOWSKI, J., RASTATTER, M., and LYNCH, K., 2002, Effect of delayed auditory feedback on normal speakers at two speech rates. Journal of the Acoustical Society of American, 111, 2237-2241.

STUART, A., MILLER, R.K., KALINOWSKI, J., and RASTATTER, M.P., 1997b, The effect of speaking into a passive resonator on stuttering frequency. Perceptual and Motor Skills, 84, 1343-1346.

STUART, A., XIA, S., JIANG, Y., JIANG, T., KALINOWSKI, J., and RASTATTER, M.P., 2003, Self-contained in-the-ear device to deliver altered auditory feedback: Applications for stuttering. Annals of Biomedical Engineering, 31, 233-237.

VAN BORSEL, J., REUNES, G., and VAN DEN BERGH, N., 2003, Delayed auditory feedback in the treatment of stuttering: clients as consumers. International Journal of Language & Communication Disorders. 38, 119-29.

VAN RIPER, C, 1973, The Treatment of Stuttering, (Englewood Cliffs, NJ: Prentice Hall).

WEBSTER, R. L. and LUBKER, B. B., 1968, Interrelationships among fluency producing variables in stuttered speech. Journal of Speech and Hearing Research, 11, 754-66.

WHITE, C., KALINOWSKI, J., and ARMSON, J., 1995, Clinicians' naturalness ratings of stutterers' speech under auditory feedback conditions. Asha, 37(10), 107.

WINGATE, M. E., 1976, Stuttering: Theory and Treatment, (New York: Irvington).

ZIMMERMAN, S., KALINOWSKI, J., STUART, A., and RASTATTER, M.P, 1997, Effect of altered auditory feedback on people who stutter during scripted telephone conversations. Journal of Speech, Language, and Hearing Research, 40, 1130-1134.

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Table 1

Age (in years), Gender, and Stuttering Severity (Riley, 1994) for Participants in Experiment 1 and 2.

Participant	Age	Gender	Stuttering Severity
Experiment 1			
1	12	Male	Severe To Very Severe
2	16	Male	Severe
3	34	Male	Severe To Very Severe
4	18	Male	Moderate
5	25	Male	Mild To Moderate
6	26	Male	Very Severe
7	22	Female	Moderate To Severe
Experiment 2			
1	9	Male	Severe
2	12	Male	Moderate To Severe
3	14	Male	Severe
4	15	Male	Moderate
5	22	Male	Very Severe
6	27	Male	Moderate
7	49	Male	Very Severe
8	54	Female	Severe To Very Severe

Table 2

Summary Table For The Four-Factor Mixed Analysis Of Variance Investigating Mean Proportions Of Stuttering Events As A Function Of Group, Time, Speech Task, and Device.

Source	*df*	*F*	*p*	η^2	ϕ
Group	1	1.67	.24	.22	.19
Time	1	0.011	.92	.002	.051
Time X Group	1	0.00016	.99	.00	.050
Speech Task	1	1.34	.29	.18	.17
Speech Task X Group	1	0.058	.82	.010	.055
Device	1	23.71	.0028*	.80	.98
Device X Group	1	2.80	.15	.32	.29
Time X Speech Task	1	0.63	.46	.095	.10
Time X Speech Task X Group	1	2.75	.15	.31	.29
Time X Device	1	0.45	.53	.070	.088
Time X Device X Group	1	0.027	.87	.005	.052
Speech Task X Device	1	0.14	.72	.023	.062
Speech Task X Device X Group	1	0.19	.66	.031	.066
Time X Speech Task X Device	1	2.42	.17	.29	.26
Time X Speech Task X Device X Group	1	3.72	.10	.38	.37

Note. *Significant at $p < .05$; repeated measures factor p values following a Huynh-Felt correction; effect size indexed by η^2; and power indexed by ϕ at α of .05.

Table 3

Summary Table Of Four Sets Of Planned A Priori Orthogonal Single-df Contrasts To Evaluate The Differences In Mean Naturalness As A Function Of Group And Speech Task.

Contrast	*df*	*F*	*p*	η^2	ϕ
Youth Reading					
Device vs. No Device	1	123.35	< .0001*	.90	1.00
Initial Visit With Device vs. Four Months With Device	1	0.020	.89	.001	.052
Youth Monologue					
Device vs. No Device	1	90.23	< .0001*	.87	1.00
Initial Visit With Device vs. Four Months With Device	1	8.41	.012*	.38	.77
Adult Reading					
Device vs. No Device	1	114.87	< .0001*	.89	1.00
Initial Visit With Device vs. Four Months With Device	1	0.23	.64	.016	.073
Adult Monologue					
Device vs. No Device	1	463.78	< .0001*	.97	1.00
Initial Visit With Device vs. Four Months With Device	1	3.79	.072	.21	.44

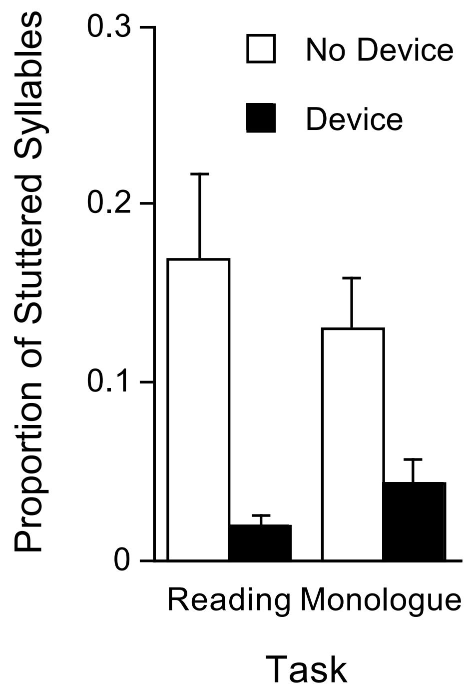
Note. *Significant at $p < .05$; effect size indexed by η^2; and power indexed by ϕ at α of .05.

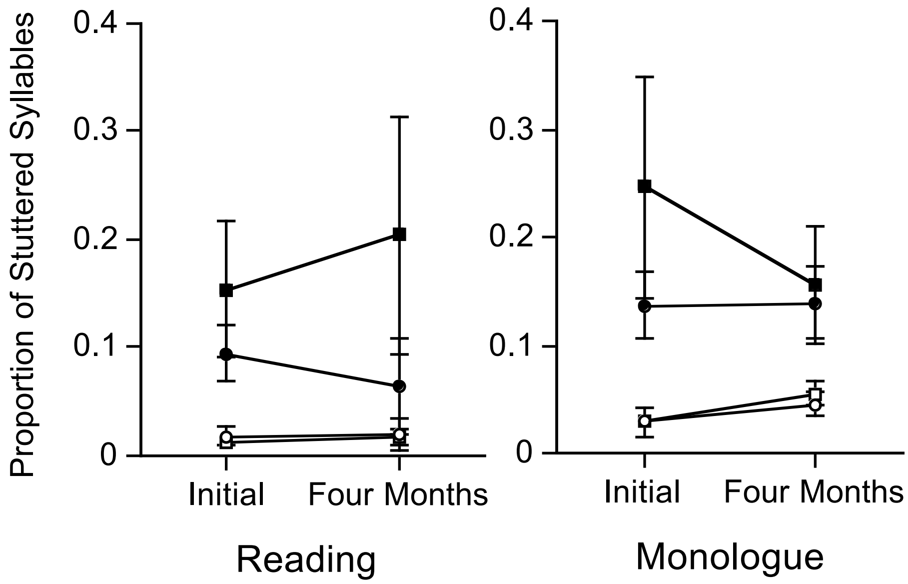
Figure Captions

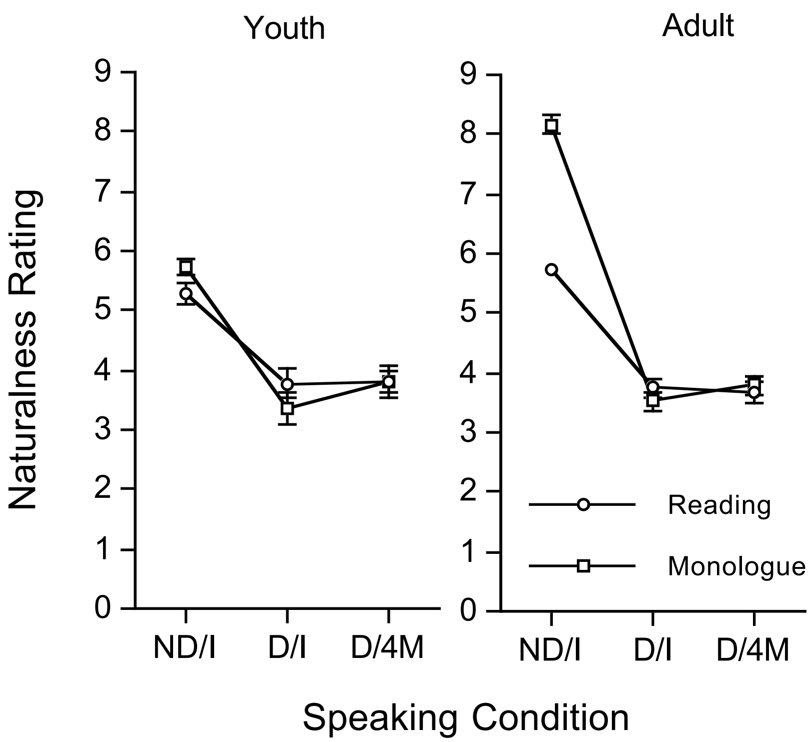
Figure1. Mean proportion of stuttering events per 300 syllables as a function of device (i.e., present vs. absent) and speech task (i.e., reading vs. monologue). Error bars represent plus one standard error of the mean.

Figure 2. Mean proportion of stuttering events per 300 syllables as a function of group (i.e., youth vs. adult), time (i.e., initial fitting vs. four months), speech task (i.e., reading vs. monologue), and device (i.e., present vs. absent). Error bars represent plus/minus one standard error of the mean. Circles and squares represent youth and adult groups, respectively. Filled and open symbols represent device absent and device present conditions, respectively.

Figure 3. Mean naturalness rating as a function of group (i.e., youth vs. adult), speech task (i.e., reading vs. monologue), and speaking condition (i.e., initial visit without device vs. initial visit with device vs. four months with device). Error bars represent plus/minus one standard error of the mean. Note: ND = No Device, D = device, I = Initial Visit, and 4M = Four Months.


Proportion of Stuttered Syllables
0.3
0.2
0.1
0
No Device
Device
Reading
Monologue
Task


Proportion of Stuttered Syllables
0.4
0.3
0.2
0.1
0
Initial
Four Months
Reading
Monologue



Youth
Adult
9
8
7
6
5
4
3
2
1
0
Naturalness Rating
ND/I
D/I
D/4M
Reading
Monologue
Speaking Condition