

Investigations Of The Impact Of Altered Auditory Feedback In-The-Ear Devices On The Speech
Of People Who Stutter: One-Year Follow-Up

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Abstract

Purpose: This study examined objective and subjective measures of the effect of a self-contained ear-level device delivering altered auditory feedback (AAF) for those who stutter 12 months following initial fitting with and without the device.

Method: Nine individuals with developmental stuttering participated. In Experiment 1, the proportion of stuttering was examined during reading and monologue. A self-report inventory inquiring about behaviour related to struggle, avoidance and expectancy associated with stuttering was examined in Experiment 2. In Experiment 3, naïve listeners rated the speech naturalness of speech produced by the participants during reading and monologue.

Results: The proportions of stuttering events were significantly ($p < 0.05$) reduced at initial fitting and remained so 12 months post follow-up. After using the device for 12 months, self-reported perception of struggle, avoidance and expectancy were significantly ($p < 0.05$) reduced relative to pre-fitting. 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 for both reading and monologue ($p < 0.0001$).

Conclusions: These findings support the notion that a device delivering AAF is a viable therapeutic alternative in the treatment of stuttering.

Key words: Stuttering, altered auditory feedback, in-the-ear device

Investigations Of The Impact Of Altered Auditory Feedback In-The-Ear Devices On The Speech Of People Who Stutter: One-Year Follow-Up

The development of the first self-contained in-the-ear device delivering altered auditory feedback for the amelioration of stuttering was recently reported.¹ The device houses a microdigital signal processor core that reproduces the high fidelity of unaided listening and auditory self-monitoring while at the same time delivering altered auditory feedback (AAF). Cosmetically appealing custom in-the-ear devices in the form of both in-the-canal and completely in-the-canal designs deliver delayed auditory feedback (DAF) and frequency altered feedback (FAF) signals in combination or isolation to the user. Programming of the device is achieved through a personal computer, interface, and fitting software.

The efficacy of the self-contained ear-level device for those who stutter was first reported in three experiments.² In the first experiment, the effect of the device was investigated with those who stutter during reading and monologue. Two adolescents and six adults participated. They presented with developmental stuttering that was exhibited at least 5% stuttered syllables. ‘Stock’ completely-in-the-canal shells were coupled to a commercially available foam earpiece and fitted monaurally for each participant. FAF was plus 500 Hz and combined with a DAF setting of 60 ms for all participants. The proportion of stuttered syllables was reduced by approximately 90% and 67% during reading and monologue, respectively. In Experiment 2, the effect of custom made in-the-canal and completely-in-the-canal devices on reading and monologue on stuttering proportion was examined with four adult and four youth participants who stutter during initial fitting and at four months follow-up. The same FAF and DAF parameters were utilized as in Experiment 1. 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. Approximately an 80 % reduction in the proportion of stuttered syllables was observed with the device in place relative to not in place when the data were collapsed across speech task, time, and group. In Experiment 3, 15 naïve young adults rated the naturalness of speech produced by the participants in Experiment 2 without the device at the initial visit and four months later. They rated the speech samples from those who stutter while wearing the device to be 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. In other words, the perceived naturalness of speech samples from people who stutter was significantly improved with the device and remained so over time.

Subjective self-report measures have also been reported for the self-contained device. Kalinowski³ in a self-report case study first described the effectiveness of the device in inhibiting stuttering during one hundred hours of university teaching: After ten months of use, the author was relatively free from stuttering. It was reported that feelings of fear were reduced, fluent speech was produced spontaneously and without effort, and speech was natural sounding with the device in place.

In a more comprehensive study Kalinowski et al.⁴ described overall satisfaction and self-perceived differences in stuttering behaviours prior to and following fitting of the self-contained ear-level device among a cohort that purchased the device from three different distribution centers. Questionnaires were mailed to 250 individuals. Forty-two percent ($n = 105$) of questionnaires were returned including those from 85 men and boys and 20 women and girls aged 7 to 81 years ($M = 32$ years). The average time period following fitting was six months. Seven-point Likert scales (i.e. with one representing the most positive and seven the most

negative) were used to probe their perceptions of stuttering prior to and following fitting. The following parameters were examined: overall stuttering frequency, use of speech and situational avoidances, speech naturalness, frequency of stuttering while using the telephone, frequency of telephone use and stuttering frequency in conversation and overall satisfaction with the device. Respondents reported statistically significant ($p < 0.001$) improvements (i.e. more positive ratings) across each of the six parameters. The overall satisfaction rating for the device was positive with a median score of 2.0 on the seven-point scale. The authors offered that these findings suggest that this first-generation self-contained ear-level device for those who stutter offers an efficient and effective means of stuttering amelioration as perceived by the user.

In this paper, we continue to report the therapeutic application of the first self-contained ear-level device delivering AAF for those who stutter after one year of use through both objective and subjective measures in three experiments. In Experiment 1, the effect of custom made in-the-canal and completely-in-the-canal devices on the proportion of stuttering was examined during reading and monologue at 12 months post fitting and compared to previously reported results during initial fitting and at four months follow-up. In Experiment 2, a self-report inventory inquiring about behaviour related to struggle, avoidance and expectancy was administered to the participants in Experiment 1 at 12 months following their initial fitting. They were instructed to answer questions with regards to their speech before being fitted with the device and then to answer the same questions again regarding their speech after wearing the device for 12 months. In Experiment 3, naïve listeners rated the naturalness of speech produced by the participants in Experiment 1 during reading and monologue with and without the device at initial visit, reading and monologue with the device at four months, and reading and monologue with and without the device at 12 months.

Experiment 1

MethodParticipants

Nine individuals with developmental stuttering participated. Participants exhibited 5% stuttered syllables or higher in either reading or monologue tasks. They were recruited at the Speech-Language & Hearing Clinic, Department of Communication Sciences and Disorders, East Carolina University, Greenville, NC, USA. Informed consent was obtained from all the participants. 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. Five participants were adults ($M = 41.4$ years $SD 14.7$) and four were youths (i.e. one child and three adolescents; $M = 13.5$ years $SD 2.6$). The Stuttering Severity Instrument for Children and Adults⁵ was utilized to determine participants' severity of stuttering. A certified speech-language pathologist administered this standard clinical assessment tool once. Speech or language disorders other than stuttering were not reported. 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 HL⁶ or better at octave frequencies from 250 to 8000 Hz and normal bilateral middle ear function.⁷

Table 1 displays demographic information for the individual participants.

[Insert table 1 about here]

Apparatus

All speech samples were recorded in quiet therapy rooms with a video camera (Panasonic AG-188). A self-contained in-the-ear prosthetic fluency device was utilized. Personal ear-level devices were constructed in either in-the-canal or completely-in-the-canal custom-made shell

designs. The shells were fabricated from individual ear mold impressions. Five adults were fit with completely-in-the-canal devices while the four youths were fit with in-the-canal devices. Completely-in-the-canal designs were afforded to the adults due to larger canal sizes. The device is described in detail elsewhere.¹ A description of how devices are programmed via a laptop personal computer was outlined previously.² The device settings were the same for all participants with a DAF setting of 60 ms combined with FAF at plus 500 Hz. Volume was adjusted to a preferred listening level for all participants.

Procedure

All participants received a standard clinical workup during their initial assessment. After consenting to participate, participants had an ear mold impression taken by a certified clinical audiologist for the device construction. The choice of ear to be fit with the device was determined by each participant. Two participants chose the left ear while seven the right ear. Participants returned within three weeks to receive their customized device and undergo a 45 to 90 minute fitting and orientation.²

With and without the device in place, participants read different 300 syllable passages extracted from junior high texts with similar theme and syntactic complexity and generated 300 syllables of monologue speech at their normal rate with normal vocal intensity. A research assistant or one of the experimenters accompanied the participant in the test room to serve as a listener. For the monologue task, participants were prompted to discuss a general topic(s). 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 Stuart⁸). Participants were given an orientation to the device where they determined their preferred listening level and

listened to the altered signal generated by the device. Minor alterations to their speech production patterns were encouraged to highlight the altered signal. Intermittent vowel prolongation and the use of starters (e.g. 'um', 'ah', etc.) were also trained for intermittent use to help initiate or maintain the altered signal.²

Conditions of reading and monologue were counter balanced. A research assistant accompanied each participant in the therapy room during testing. If needed, the research assistant prompted the participant to ensure monologue output was maintained. In an effort to eliminate any possible carry-over fluency effects of the device, participants produced speech without the device in the control condition first. At four (plus/minus one week) and 12 (plus/minus two weeks) months post fitting, participants returned to the clinic for follow-up testing. Each participant produced 12 samples of speech in total (i.e. four during each of the initial assessment, four month assessment, and 12 month assessment).

A research assistant counted stuttered syllables in the first 300 syllables produced by the participants in each condition. A stuttered syllable was defined as a part-word prolongation, part-word repetition, or inaudible postural fixation (i.e. silent block). Stuttered syllables were recalculated for 15% of the speech samples chosen at random. Intrajudge syllable-by-syllable agreement was 0.94, as indexed by Cohen's kappa.⁹ 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. A Cohen's kappa value above 0.75 represents excellent agreement beyond chance.¹⁰

Results

The data from all participants except Participant #8 was reported previously for the initial and four month assessment.² Participant #8's data is included in the initial data described herein.

Participant #4 dropped out after four months. 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), time (i.e. initial vs. four months vs. 12 months), and speech task (i.e. reading vs. monologue) are illustrated in figure 1.

[Insert figure 1 and table 2 about here]

The participants' proportional scores were transformed to arcsine units prior to subjecting them to inferential statistical analysis. A three-factor mixed analysis of variance (ANOVA) was undertaken to investigate differences in mean proportions of stuttering events as a function of device, time, and speech task. The ANOVA was performed using the SAS System Mixed Procedure (SAS Institute, Version 6.12). This procedure is appropriate for data sets with missing data as long as the missing data are random.¹¹ The summary of the analysis is presented in table 2. As evident in table 2, significant main effects of device and speech task were found ($p < 0.05$). All other main effects and interactions were not significant ($p > 0.05$).

Discussion

The proportions of stuttering events were significantly reduced with persons who stutter while experiencing AAF via an in-the-ear device at initial fitting and remained so 12 months post follow-up. Contrary to our previous report², there was a significant difference in the proportions of stuttering events as a function of speech task. That is, a greater amount of stuttering was observed during monologue (see figure 1). The proportion of stuttered syllables was reduced, however, by approximately the same amount (cf. 85% and 75% during reading and monologue, respectively).

Experiment 2

MethodParticipants

The same nine individuals with developmental stuttering described in Experiment 1 partook in Experiment 2 with the exception of Participant # 4 (see table 1).

Apparatus

The Perceptions of Stuttering Inventory¹² (PSI) is a self-report inventory of three sets of 20 items randomly distributed, which inquire about behaviour related to struggle, avoidance and expectancy. The purpose of the self-report inventory is to describe in some manner the compensatory mechanisms/behaviours used by those who stutter when speaking or thinking about speaking. Behaviours range from simple avoidance of sounds to the anticipation of failure during speech attempts and efforts to cope with anticipation and experience of failure. In effect, struggle, avoidance and expectancy represent divergent expressions of anticipation and different strategies for manipulating and resolving this anticipation.¹²

Procedure

Participants privately completed in a clinical room two forms of the PSI at 12 months following the initial fitting of the fluency device. Participants were instructed to answer the questions with regards to their speech before being fitted with the device and again regarding their speech after wearing the device for 12 months. Instructions for the PSI for the 12-month follow-up post treatment condition were verbatim from Woolf.¹² Instructions for the pretreatment condition were modified slightly to reflect self-perceptions characteristic of the participant 12 months earlier prior to the initial fitting. Both sets of instructions are presented in the Appendix.

The two forms of the questionnaires were counter balanced across participants. Administration of the two PSI questionnaires took approximately 20 minutes.

Results

The mean raw scores and standard errors for the three PSI subscales a function of device (i.e. pre-device vs. post-device) are illustrated in figure 2. A two factor repeated measures ANOVA was undertaken to examine mean score differences as a function of device and subscale. A main effect of device was found [$F(1,7) = 26.83, p < 0.001, \eta^2 = 0.79$]. No significant main effect of subscale [$F(2,14) = 0.18, p = 0.84, \eta^2 = 0.025, \phi = 0.073$] or a device by subscale interaction was evident [$F(2,14) = 3.25, p = 0.069, \eta^2 = 0.32, \phi = 0.52$].

[Insert figure 2 about here]

Discussion

Self-reported measures of struggle, avoidance and expectancy associated with stuttering were perceived to be high and equivalent prior to participants' fitting of the device. After 12 months of device, a statistically significant and equal reduction was reported. One caveat, in with the interpretation of these results, is that the administration of the PSI occurred at 12 months post-fitting. That is, query of struggle, avoidance and expectancy for the pre-device fitting occur 12 months latter. Asking participants how they felt 12 months earlier introduces possible recall, reliability, and bias issues relative to responses.

Experiment 3

Method

Participants

Twenty-seven naïve young adult undergraduate students attending East Carolina University, Greenville, NC participated in Experiment 3 ($M = 23.5$ years $SD = 5.9$; 3 males and 25

females). Participants had a negative history of speech, language, or hearing pathology and no clinical training in speech-language pathology.

Apparatus

Ten speech samples were extracted from the video recordings of each of the seven participants in Experiment 1 that data was collected at initial fitting, four months post-fitting, and 12 months post-fitting (i.e. Participants #4 and #8 were excluded). Separate 15 s audio segments of uninterrupted speech were randomly selected from each participant's speech production under the following conditions: reading and monologue with and without the device at initial visit, reading and monologue with the device at four months, and reading and monologue with and without the device at 12 months. Five additional samples came from five normal adults speakers while reading.¹³ The extraction, editing, and compact disk recording of files is described in details elsewhere.^{2, 13} A total of 75 speech samples were recorded onto a compact disk (CD) in a randomized order for rating.

Procedure

Speech naturalness ratings took place in a classroom setting as described previously.² 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 a response sheet. The response sheet contained a nine-point rating scale¹⁴ for assessing the speech naturalness for each speech sample. Participants were asked to rate each speech sample without being provided an operational definition of speech naturalness. The

listeners rated each sample for naturalness in which '1' was 'highly natural' and '9' was 'highly unnatural'. Verbal instructions were identical to that used by Martin et al.¹⁴

Results

An intraclass correlation (2,1)¹⁵ was calculated to assess interrater reliability for the 75 ratings from the 27 participants. The intraclass correlation was 0.70. Values between 0.4 and 0.75 are considered fair to good reliability while those above 0.75 are excellent.¹⁶ Listeners' ratings for speech samples were averaged to give mean rating values for the normal speakers and those who stuttered as a function of speech task (i.e. reading vs. monologue), device (i.e. with and without), and time (i.e. initial fitting vs. four months vs. 12 months). For the average ratings the intraclass correlation was 0.84. This rendered from each participant's 75 ratings 11 average ratings. The mean naturalness ratings as a function speech sample are shown in figure 3.

[Insert figure 3 and table 3 about here]

A limited number of theoretically planned single-df comparisons^{17, 18} central to the purpose of the research were undertaken for both reading and monologue samples. A summary of those contrasts is presented in table 3.

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 for both reading and monologue. For both reading and monologue, the speech naturalness ratings of samples from individuals who stuttered with the device were significantly better than without and speech naturalness ratings were significantly better for the samples at 12 months than following the initial and four month period. The naturalness ratings were significantly worse at four months for the monologue samples only. Without the device, samples from those who

stutter were significantly poorer at 12 months during reading only. As expected and consistent with our previous findings¹³, fluent normal speakers were judged to be more natural sounding than those who stutter while reading.

It is interesting to note that the speech naturalness ratings of samples at 12 months from individuals who stuttered with the device were judged to be significantly more natural than for the samples at the initial and four month period. Martin et al.¹⁴ speculated that the presence of either dysfluent episodes and or a slowed rate of speech generates in fluent speakers a perception of unnaturalness of those who stutter. It is unlikely that a decrease of dysfluent episodes at 12 months contributed to this difference in naturalness ratings. Recall from Experiment 1 that there was no significant difference in the proportions of stuttering events with the device worn during the initial, four month, and 12 month periods. Although speech rate was not measured, it is unlikely that a decrease speech rate contributed to the poorer naturalness ratings at the initial and four month period either. In our previous studies we have demonstrated that when instructed to speak at a self-imposed ‘normal’ rate, individuals who stutter generate rates that are comparable to normal conversational speech rates of fluent speakers.¹⁹⁻²² Although purely speculative, it may be the case that following prolonged exposure (i.e., in excess of four months) to AAF, stuttering episode duration is reduced which may lead to the perception of more natural sounding speech despite the fact that the total number of dysfluencies remain the same across samples. Stuttering episode duration has been observed to decrease under conditions of DAF and FAF.^{14, 23}

General Discussion

The first important finding of these experiments is that stuttering events significantly reduced with persons who stutter while experiencing AAF via an in-the-ear device. The reduction in the proportion of stuttering events experienced at initial fitting was maintained at 12

months post follow-up. This amount of stuttering inhibition is in harmony with previous reports of robust responses to AAF (i.e. reductions of greater than 70%) via electronic signal delivery.^{8, 19-22, 24-28} Further, consistent with earlier investigations, reduction of stuttering occurred with monaural feedback.²⁷ Importantly, these reductions in stuttering were accomplished primarily via a sensory modality unlike most behavioural therapies that use speech retraining of the articulatory, laryngeal, and respiratory subsystems to diminish stuttering.²⁹ However, despite the modality input difference, there is evident stability in stuttering inhibition, naturalness of speech, and recovery beyond the clinic room as reported in the PSI.

The finding of prolonged maintenance of stuttering reduction should not come as a surprise. Earlier research has demonstrated that a wearable, albeit not ear level device, delivering AAF maintained long-term stuttering inhibition.³⁰ The “Edinburgh masker” diminished stuttering in 89% of 195 persons who stutter. Six months to three years later, of 62 who were followed, 82% were found to have maintained reduced stuttering.

Contrary to our previous report², there was a significant difference in the proportions of stuttering events as a function of speech task. That is, a greater amount of stuttering was observed during monologue (see figure 1). Equivocal findings have been reported previously: Significantly more stuttering has been reported^{31, 32} during monologue speech relative to reading, while no differences have been reported³³ between the two. Nevertheless, the proportion of stuttered syllables was reduced by approximately the same amount (cf. 85% and 75% during reading monologue, respectively). Significant reduction in stuttering frequency has been reported for participants during a monologue under other forms of AAF including masked auditory feedback MAF and DAF.³⁴⁻³⁸ A greater amount of stuttering inhibition was observed, however, during monologue speech than previously reported.^{8, 39}

In this study the PSI probed self-reported measures of struggle, avoidance and expectancy associated with stuttering. The second important finding of this study was that significant self-reported improvements/reductions in core stuttering behaviours following 12 months use of the device. Simply put, experientially the disorder of stuttering was no longer perceived to be of the same magnitude after 12 months of use with the ITE device. One procedural problem addressed above was that the administration of the PSI occurred at 12 months post-fitting. Again, query of struggle, avoidance and expectancy for the pre-device fitting occur 12 months latter. Recall, reliability, and bias issues relative to responses could have been introduced. These findings, however, are consistent with previous improvements/reductions in self-reported measures of stuttering behaviour from a cohort of 105 users of the self-contained ITE device.⁴ In a similar design, where opinion was questioned following an average of six months of device use, they rated their perceptions after using the device and were also asked to recall there perceptions before fitting. They reported a perceived significant positive improvement in overall stuttering frequency, reduction in the use of speech and situational avoidances, increased speech naturalness, decreased frequency of stuttering while using the telephone, increased frequency of telephone use and decreased stuttering frequency in conversation.

Self-report measures like the PSI are paramount. For example, people who stutter often act in a manner that will purposely keep them out of conversations such as avoiding the use of telephones, making new acquaintances, and talking to people in authority (e.g. teachers and employers). Some report evading public speaking, changing the pitch of their voice when they expected to get stuck on a word, or giving excuses to talking altogether. Self-report data of this nature is essential when evaluating the success or failure of any therapeutic intervention in an

experiential disorder like stuttering. The PSI is well designed and covers a wider range of situational conditions not assessed in a clinic room. Self-report strategies are only accessible to the person who stutters and can measure experiential changes that are integral to measuring changes not assessed by overt measures such as speech naturalness, repetitions prolongations, and postural fixations.

Finally, naïve listeners found the speech samples produced by those who stutter while wearing the device to be significantly more natural sounding than those produced without the device for both reading and monologue. Further, there was a significant improvement in the speech naturalness ratings from 4 to 12 months. That is their speech following extended use became more natural sounding. These findings are consistent with the repeated findings of improved the perception of natural sounding speech at initial exposure of AAF: Previously, it was reported that speech samples generated by those who stutter while wearing the device were judged to be more natural sounding than those without the device at initial fitting and at four months post-fitting.² White et al.⁴⁰ also reported that speech-language pathology clinicians speech perceived speech produced by people who stutter under FAF significantly more natural than that produced under non-altered auditory feedback. Ingham et al.³⁹ demonstrated improved speech naturalness associated with reduced stuttering under FAF for two of four adults who stutter during both reading and monologue. Stuart and Kalinowski¹³ found speech samples produced under DAF and FAF from those who stutter were rated as significantly more natural sounding than non-altered auditory feedback for both those with mild and severe stuttering. Further, they found speech from individuals following traditional behavioural therapy (i.e. Precision Fluency Shaping Program) was rated significantly less natural sounding than that from individuals during AAF for both mild and severe stuttering. Interestingly, without the device in

place, samples from those who stutter were significantly poorer at 12 months during reading only (i.e. there was no carry-over effect). As expected, fluent normal speakers were judged to sound more natural while reading compared to those who stutter while reading using the device. This is likely due to some residual stuttering episodes in the speech samples from those who stutter. These findings support the contention that AAF benefits those who stutter through a reduction of stuttering with a gain in perceived speech naturalness.

In general, we continue to advocate the application of AAF as a therapeutic alternative. We recognize that AAF may not be the panacea for all who stutter. We continue to offer that not all individuals respond favorably to AAF. Our previous studies^{8, 19-22, 25-27} and others^{24, 28, 39} have shown varying levels of stuttering reduction under various AAF conditions. Further, in some AAF conditions, spontaneous speech from those who stutter is not judged to be natural.^{14, 39} It would be reasonable to accept that not all who stutter would benefit therapeutically from AAF in terms of stuttering reduction and improved speech naturalness.

In conclusion, we report the first long-term (i.e. 12 months) use of a monaural ITE device employing AAF (e.g. FAF, DAF) as the primary therapeutic tool of intervention to reduce overt stuttering manifestations, increase speech naturalness, and decrease self-reported avoidance, expectancy, and struggle strategies. This intervention appears to be a viable alternative to other primarily behavioural treatment modalities for stuttering that are now being offered. In evaluating treatment approaches for stuttering, we suggest the importance of focusing on a holistic view of success (i.e. subjective and objective measures of core stuttering behaviours). For this group, the device was a success; we hope in the future efficacy studies will also measure other aspects such as ease of use, communication with the therapist, suggestions and complaints. In the future, studies should retain objective measures of reducing stuttering but also continue to

utilize self-report instruments to assess the user needs and generalization of stuttering inhibition to outside the clinic. We also anticipate examining larger samples of those who stutter with additional instruments and with later generations of the device.

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Appendix

The following instructions were provided to participants in Experiment 2 for completion of the PSI:

Post Treatment Following 12 Months Of Device Use:

Here are 60 statements about stuttering. Some of these may be characteristic of your stuttering. Read each item carefully and respond by placing a check in the square if the item describes you. Characteristic of me refers only to what you do now, not to what was true of your stuttering in the past and which you no longer do; and not what you think you should or should not be doing. Even if the behaviour described occurs only occasionally or only in some speaking situations, if you regard it as characteristic of your stuttering, place a check mark in the square.¹¹

Pretreatment Prior To Device Fitting:

Here are 60 statements about stuttering. Some of these may be characteristic of your stuttering. Read each item carefully and respond by placing a check in the square if the item describes you. Characteristic of me refers only to what you did 12 months earlier prior to fitting of the device. Even if the behaviour described occurred only occasionally or only in some speaking situations, if you regarded it as characteristic of your stuttering, place a check mark in the square.

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Table 4

Age (in years), Gender, Stuttering Severity, Device Ear, Device Type, and Data Collection Period (in months) for Participants in Experiment 1 and 2.

<u>Participant</u>	<u>Age</u>	<u>Gender</u>	<u>Stuttering Severity</u>	<u>Device Ear</u>	<u>Device</u>	<u>Data Collection</u>
1	10	Male	Severe	Right	ITC	0, 4, & 12
2	13	Male	Moderate To Severe	Right	ITC	0, 4, & 12
3	15	Male	Severe	Right	ITC	0, 4, & 12
4	17	Male	Moderate	Left	ITC	0 & 4
5	23	Male	Very Severe	Right	CIC	0, 4, & 12
6	28	Male	Moderate	Left	CIC	0, 4, & 12
7	50	Male	Very Severe	Right	CIC	0, 4, & 12
8	51	Male	Severe	Right	CIC	0 & 12
9	55	Female	Severe To Very Severe	Right	CIC	0, 4, & 12

Note. ITC = in-the-canal and CIC = completely-in-the-canal. The Stuttering Severity Instrument for Children and Adults⁵ was employed to determine stuttering severity for each participant.

Table 5

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.

	<u>Source</u>	<u>df</u>	<u>F</u>	<u>p</u>
Device		1	84.61	<.0001*
Time		2	0.64	.54
Speech Task		1	10.24	.01*
Device X Time		2	0.87	.43
Device X Speech Task		1	0.14	.72
Time X Speech Task		2	0.18	.84
Time X Speech Task X Device		2	0.32	.73

Note. *Significant at $p < .05$; effect size and power are not calculated in the SAS System Mixed Procedure (SAS Institute, Version 6.12).

Table 6

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.

<u>Contrast</u>	<u>df</u>	<u>F</u>	<u>p</u>	<u>η^2</u>	<u>ϕ</u>
<u>Reading</u>					
Device vs. No Device	1	112.16	<.0001*	.81	1.0
Initial Visit With Device vs. Four Months With Device	1	2.40	.133	.08	.32
Initial Visit and Four Months With Device vs. Twelve Months With Device	1	87.14	<.0001*	.77	1.0
Initial Visit Without Device vs. Twelve Months Without Device	1	12.06	<.002*	.32	.92
With Device vs. Normals	1	217.80	<.0001*	.89	1.0
<u>Monologue</u>					
Device vs. No Device	1	483.10	<.0001*	.95	1.0
Initial Visit With Device vs. Four Months With Device	1	31.83	<.0001*	.55	1.0
Initial Visit and Four Months With Device vs. Twelve Months With Device	1	87.14	<.0001*	.77	1.0
Initial Visit Without Device vs. Twelve Months Without Device	1	1.88	<.18	.067	.26

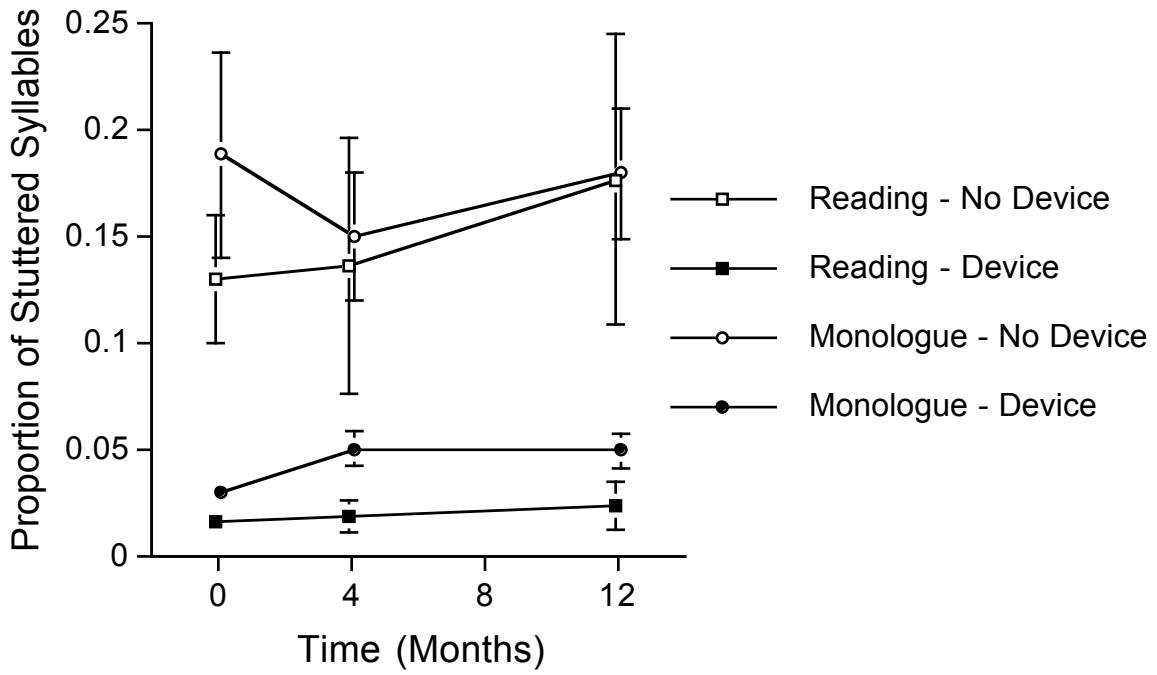
Note. *An α of 0.5 was adopted as the criterion for significance. Corrections for family wise error are suggested¹⁷ only when the number of single-df planned comparisons exceeds df_a. In this case nine single-df planned comparisons were made relative to 10 degrees of freedom. Effect size and power are indexed by η^2 and ϕ at α of .05, respectively.

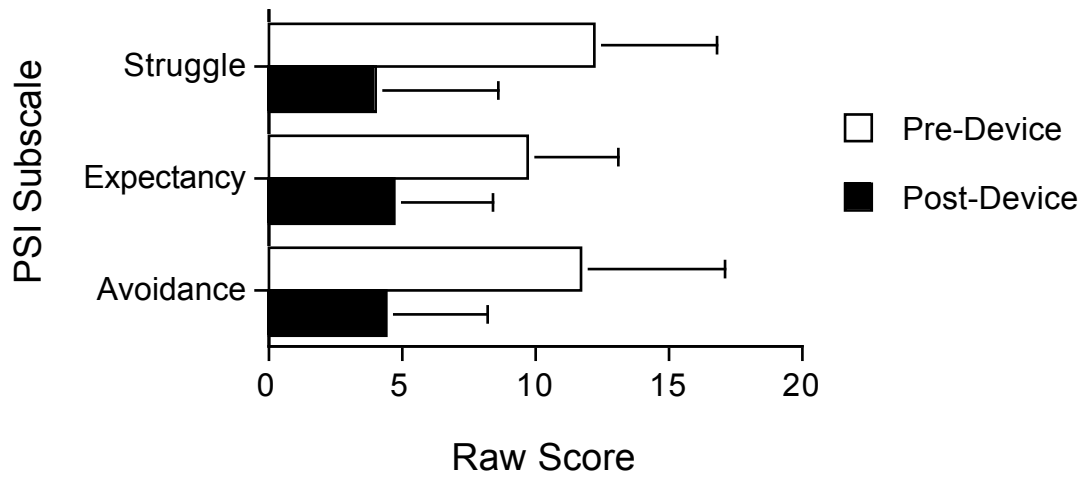
Figure Captions

Figure 1. Mean proportion of stuttering events per 300 syllables as a function of time (i.e. initial fitting or 0 months, four months, and 12 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.

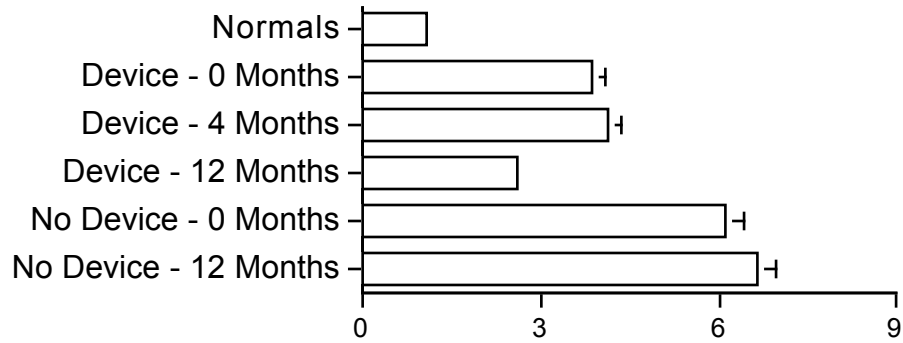
Figure 2. Mean raw scores of the three PSI subscales a function of pre-device vs. post-device fitting. Error bars represent plus one standard error of the mean.

Figure 3. Mean naturalness rating as a function of speech task (i.e. reading vs. monologue), device (i.e. present vs. absent), and time (i.e. initial fitting or 0 months, four months, and 12 months). Error bars represent plus/minus one standard error of the mean.





Reading



Monologue

