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Research Article

Efficacy of the Modifying Phonation Intervals (MPI) Stuttering Treatment Program With Adults Who Stutter

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Purpose: This study compared a new adult stuttering treatment program (Modifying Phonation Intervals, or MPI) with the standard of care for reducing stuttered speech in adults (prolonged speech).
Method: Twenty-seven adults who stutter were assigned to either MPI or prolonged speech treatment, both of which used similar infrastructures. Speech and related variables were assessed in 3 within-clinic and 3 beyond-clinic speaking situations for participants who successfully completed all treatment phases.
Results: At transfer, maintenance, and follow-up, the speech of 14 participants who successfully completed treatment was similar to that of normally fluent adults. Successful participants also showed increased self-identification as a "normal speaker," decreased self-identification as a "stutterer," reduced short intervals of phonation, and some increased use of longer duration phonation intervals. Eleven successful participants received the MPI treatment, and 3 received the prolonged speech treatment.
Conclusions: Outcomes for successful participants were very similar for the 2 treatments. The much larger proportion of successful participants in the MPI group, however, combined with the predictive value of specific changes in PI durations suggest that MPI treatment was relatively more effective at assisting clients to identify and change the specific speech behaviors that are associated with successful treatment of stuttered speech in adults.

Literature reviews and meta-analyses consistently identify prolonged speech (Goldiamond, 1965) as the most effective option for improving the speech of adults who stutter (Andrews, Guitar, & Howie, 1980; Bothe, Davidow, Bramlett, & Ingham, 2006; Ingham, 1984). Boberg and Kully (1994), for example, reporting on the ISTAR Comprehensive Stuttering Program (Boberg & Kullyi, 1985), found that mean percent syllables stuttered (%SS) during a beyond-clinic telephone conversation changed from 19.59 %SS pretreatment to 1.29 %SS posttreatment for 17 adults, and from 14.32 %SS to 1.75 %SS for 25 adolescents, with 14/17 adults and 11/25 adolescents displaying less than 1.0 %SS at posttreatment. Subsequent evaluations of Boberg and Kully's program have continued to show positive results, including studies using measures of self-identification as "a normal speaker" versus as "a stutterer" (Boberg & Kully, 1994, p. 1056) and speech naturalness (Teshima, Langevin, Hagler, & Kully, 2010), use of the treatment with Dutch speakers (Langevin et al., 2006), and evaluation of treatment outcomes in beyond-clinic settings at up to 5 years posttreatment (Langevin, Kully, Teshima, Hagler, & Prasad, 2010).

Long-term posttreatment results for prolonged speech studies tend to be complicated, however, by the related problems of relapse and attrition, or both. In Boberg and Kully's (1994) study, mean %SS had risen to 6.03 %SS for adults and 3.89 %SS for adolescents 12 months posttreatment. The intensive computerized Kassel Program (Euler & Wolff von Gudenberg, 2000; Euler, Wolff von Gudenberg, Jung, & Neumann, 2009), similarly, has provided 1–3-year follow-up data showing approximately 70%–75% sustained and generalized reductions in %SS scores for at least 69/400 enrolled participants. The studies that report better maintenance of positive treatment effects often provide data from only a small proportion of participants, suggesting that if the entire group had remained in the treatment program, the mean performance would be poorer. Onslow, Costa, Andrews, Harrison, and Packman (1996), for example, reported zero or near-zero stuttering and naturalness ratings below 3 (i.e., within the normal range) on the 9-point

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speech naturalness scale (Martin, Haroldson, & Triden, 1984) for beyond-clinic recordings of speech at 3 years posttreatment for an intensive prolonged speech program devised in the 1980s (Ingham, 1987), but only 12 of 32 original participants were reflected in these data. Similar problems confounded the findings of a more recent study by O'Brian, Onslow, Cream, and Packman (2003).

Other difficulties with some reports of what appear to be positive prolonged speech treatment outcomes include the poor methodological quality of many treatment studies (Bothe et al., 2006; Nye et al., 2013), the only occasional use of ecologically valid assessments such as speech during telephone conversations (Bothe et al., 2006) or speaker-selected difficult speaking tasks (Ingham, Ingham, & Bothe, 2012), and some evidence that the efficacy of prolonged speech treatment may be influenced by the pretreatment severity of stuttering. Hancock and Craig (1998), for example, investigated behavioral and personality variables that might interact with follow-up findings in young adolescents treated by prolonged speech. They found that only "pre-treatment stuttering frequency . . . and trait anxiety post-treatment significantly predicted stuttering frequency 1-year post-treatment" (p. 31). Boberg and Kully (1994), similarly, reported a .62 correlation between pretreatment %SS scores in telephone conversations and scores 12 months after treatment. It is important to note, however, that Boberg and Kully's data also show correlations of .63 between %SS immediately posttreatment and %SS at 12 months posttreatment, and of .84 between 4 months posttreatment and 12 months posttreatment. Hence, the trend of speech performance immediately *after* treatment may actually account for much more of the long-term or follow-up variance (71%) than pretreatment performance (38%), a possibility that has not been systematically investigated in previous studies.

Overall, prolonged speech remains the standard of care for adults who stutter. It is the best supported of current options, and there is no evidence to support such positive outcomes for other approaches (Bothe et al., 2006). Nevertheless, the need remains for treatments that can more predictably result in stutter-free speech that is natural sounding, acceptable to the speaker or consistent with desirable affective or cognitive changes, and durable across time and across clinically relevant speaking situations, without the problems of relapse or attrition.

There are also other, more fundamental problems with prolonged speech—a speech pattern so labelled by Goldiamond (1965) as resulting from speaking during delayed auditory feedback (DAF). These problems were earlier summarized by Ingham et al. (2001, p. 1230) as follows:

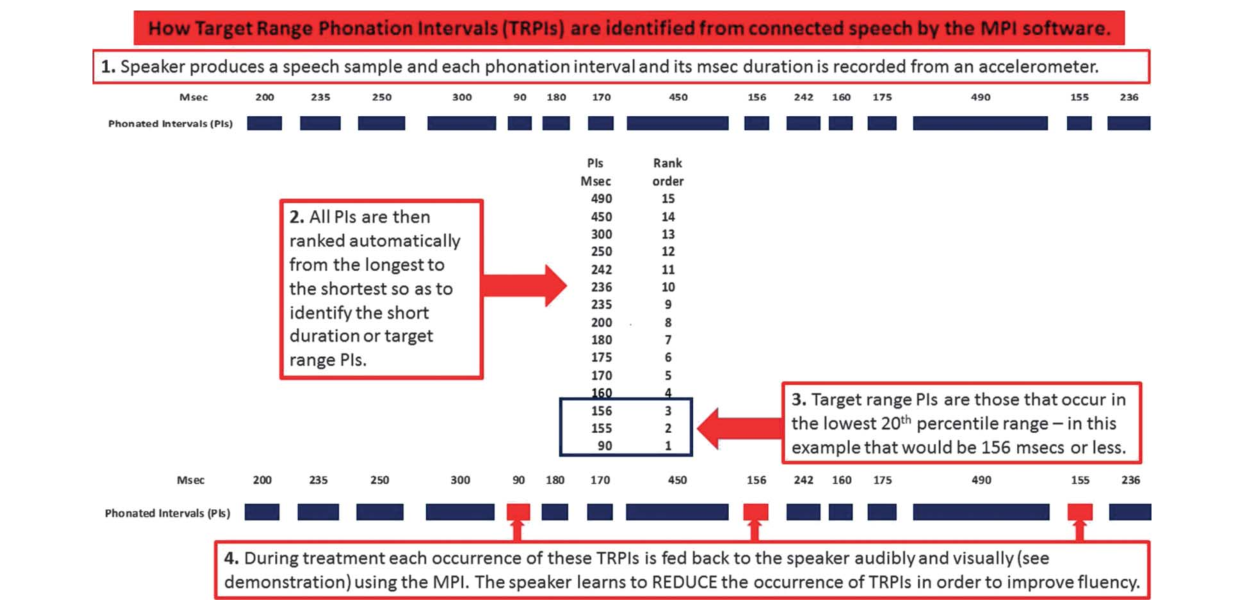
> Goldiamond (1967) actually first highlighted one of the continuing problems with prolonged speech: It is not a completely predictable response to DAF and largely depends on instructional training. Indeed, DAF ultimately became an almost irrelevant adjuvant of prolonged speech (see Ingham, 1984, Chapter 10). Furthermore, the features of this pattern that needed to be trained were only vaguely defined and, probably for that reason, have never been clearly demonstrated to be functional within a treatment context (see Ingham, 1993, for a review). These features are usually described as "continuous vocalization," often accompanied by "soft contacts," "gentle onsets," and "easy onsets" (see Webster, 1974), but few attempts have been made to specify their parameters. One legacy of this situation is Onslow and O'Brian's (1998) demonstration of poor inter- and intraclinician agreement among clinicians trying to identify these features during treatment. Borden, Baer, and Kenney (1985) and Peters, Boves, and van Dielen (1986) used acoustic rise time, or the intensity-level gradient, of an utterance onset to specify the occurrence of "easy onsets" in the speech of persons who stutter. This is also consistent with the operation of the Voice Monitor device (Webster, 1977) that is used within the Precision Fluency Shaping treatment program (Webster, 1980). However, it has yet to be demonstrated that manipulations in acoustic rise time have functional control over stuttering.

The endemic problems with prolonged speech described in this article remain as true today as they were in 2001.

Modifying Phonation Intervals

As an attempt to solve some of these problems, the first author and colleagues have investigated the effects of what might be described as an opposite approach. Instead of focusing on prolonging or increasing phonation durations, persons who stutter (PWS) can reduce the frequency with which they produce short intervals of phonation while speaking (Gow & Ingham, 1992; Ingham, Montgomery, & Ulliana, 1983). The premise underlying these studies was that part of the effectiveness of prolonged speech might depend on reducing the frequency of short intervals of phonation, rather than increasing the frequency of longer intervals. In these studies, phonation was operationally defined as an accelerometer- or electroglottograph-detected signal recorded from the throat surface at the thyroid prominence and interpreted as reflecting vocal fold vibration. The duration of the signal (excluding signal-off periods of 10 ms or less) constituted a phonation interval (PI). In other words, an accelerometer-detected vibration for 200 ms, preceded and followed by more than 10 ms during which no vibration is detected, would be described as one 200-ms PI. Initial investigations demonstrated that controlled decreases in short PIs produced a reduction in stuttering frequency and that the resulting speech was natural sounding (Ingham et al., 1983), potentially resolving this fundamental concern about some prolonged speech treatments. Specifically, Ingham et al. (1983) demonstrated that stuttering could be increased and decreased in two adult male PWS by teaching them to increase or decrease, by at least 50% relative to base rate, the frequency of PIs within the range of 10–150 ms or 10–200 ms. In subsequent studies, the lower limit of the duration range used in treatment and research (i.e., target range PIs, TRPIs) was increased to at least 30 ms because some head movement and swallowing actions were found

Figure 1. This figure illustrates (a) how the MPI program collects phonated intervals; (b) how the entire corpus of PIs is then ranked from the longest to the shortest duration PI; (c) how the target range is identified by locating the bottom 20th percentile or quintile range of the ranked distribution; and (d) how PIs that occur within the TRPI range (now shown in red) are identified in real time (i.e., during speech) with an audible and visual stimulus being immediately transmitted to the speaker. MPI = Modified Phonation Intervals treatment; PI = phonation interval.



to produce false positive PIs in the 10- to 30-ms range. Figure 1 shows graphically the measurement of PIs and the determination of one speaker's TRPIs.

The requirement to reduce by 50% those PIs that fall into the speaker's own baseline range of shortest PIs, or to reduce by 50% those PIs that are between 30 and 150 ms in duration, has proven to be both functional and predictive. It is important to recognize, however, that there is no evidence that the distribution of PIs in adult PWS differs significantly from the distribution that typifies normally fluent speakers, including PIs within the 30–150-ms range (Godinho, Ingham, Davidow, & Cotton, 2006). That is, prior to treatment, PWS do not necessarily produce more short PIs in their connected speech than normally fluent speakers. Nevertheless, investigations by Davidow, Bothe, Andreatta, and Ye (2009), for instance, have shown that some well-known fluency inducing conditions (chorus reading, prolonged speech, singing, and rhythmic stimulation) are associated with approximately 50% reductions in PIs within the range of 51–150 ms. Most important for the development of improved treatment options, the results of these PI investigations were used to develop a treatment known as Modifying Phonation Intervals (MPI). In an evaluation of the MPI treatment with five adults who stuttered, Ingham et al. (2001) demonstrated that all five achieved stutter-free and natural-sounding speech within and beyond the clinic environment, and all five maintained those gains for at least 12 months (these five participants are included in the present study; see Methods). These successful outcomes suggested that the MPI treatment could represent an improved variation on prolonged speech treatments.

The present study was designed, therefore, to compare MPI treatment to prolonged speech treatment for larger groups of participants. This study used a treatment comparison design that equated all other aspects of treatment infrastructure and delivery for both treatments and that also allowed the simultaneous investigation of some of the stuttering treatment outcome issues discussed in previous paragraphs. Specific research questions are as follows:

1. Are there significant differences in speech performance and self-identification (as *stutterer* or *normal speaker*) outcomes for participants who successfully complete the MPI treatment as compared with those who successfully complete the current best treatment, prolonged speech?
2. Are there significant differences in PI distributions during treatment that can differentiate between participants who will succeed in completing the long-term maintenance phase of either program and those who do not succeed?
3. Do participants who succeed in completing either program achieve levels of speech performance, self-identification, and PI distributions that are not significantly different from those found in normally fluent speakers?

Method

Participants

Twenty-seven PWS (22 men, five women; age range 18–64 years; *M* = 35.9 years; median = 35 years) and eight adults who do not stutter (controls, CONT; six men, two women; age range 20–64 years; M = 37.8 years; median = 32 years) participated in this study, which was conducted in the Department of Speech and Hearing Sciences, University of California, Santa Barbara, California, and the Research Imaging Institute, University of Texas Health Science Center, San Antonio, Texas. All were volunteers identified from treatment waiting lists at either site or via advertisements in San Antonio, Austin, and Houston. The first five PWS participants were assigned to MPI treatment, and most of their data were reported in Ingham et al. (2001); the next 22 were randomly assigned to either MPI (n = 12) or prolonged speech (PS) treatment (n = 10).[1] CONT participants were matched, by gender and age (within ± 5 years), with eight PWS participants; they completed two data-collection sessions but no treatment. The CONT group were selected for three purposes: (a) to be used within the brain-imaging section of this study, the results of which were reported earlier (see Ingham, Wang, Ingham, Bothe, & Grafton, 2013); (b) to provide control group PI data for comparison with the PWS PI data and help establish the consistency of normally fluent speakers' PI data over time; and (c) to provide speech and self-report data necessary to be able to interpret the PWS data as similar to or different from those of speakers who do not stutter.[2]

All PWS participants self-reported stuttering since early childhood and displayed chronic stuttering as confirmed by the principal investigator and a certified speech-language pathologist using standard clinical assessments (Ingham & Costello, 1985). All participants were right-handed (>+80 on the Edinburgh Handedness Inventory; Oldfield, 1971]; displayed no signs of any neurologic disorder other than stuttering; reported no other current speech, language, cognitive, or behavioral disorder; and passed a hearing screening. All PWS participants had experienced various therapies, but no participant reported receiving treatment for stuttering during the preceding 3 years. Ten of the participants' previous therapies had included a Fluency Shaping procedure that utilized a version of prolonged speech; they were randomly assigned to either the MPI or PS group. All PWS participants produced at least 3 %SS during at least one of three 3-min within-clinic pretreatment speaking tasks (oral reading, monologue, and a telephone conversation). All CONT participants met the same selection criteria, except that they were required to produce 0 %SS during each of the three speaking tasks and not report either a history of or the presence of stuttering.

[1] Data through the maintenance phase for the first five participants were presented by Ingham et al. (2001).

[2] We actually recruited sufficient controls so as to have matched numbers, but many dropped out because they were not willing to complete a second positron emission tomography (PET) scanning session. Each PET session took about 3 hours and required the participant to be injected with a radioactive tracer—something many preferred to avoid doing a second time. Nonetheless, the eight controls did provide comparisons for PI counts and speech naturalness ratings for the present study. Their repeated PET scanning data were crucial for the data evaluation reported earlier in the Ingham et al. (2013) article.

Treatment Format and Programs

Commonalities across MPI and PS treatment programs. Both the MPI and the PS treatments used in this study have been reported elsewhere (for MPI: Ingham, 1999; Ingham et al., 2001; Ingham et al., 2013; for PS: Ingham, 1987; Onslow et al., 1996). Each is organized as five consecutive phases: pretreatment, establishment, transfer, maintenance, and follow-up. A trained clinician directs the pretreatment phase (and all subsequent phases), which includes at least three data-collection sessions (see below), scheduled at 2-week intervals. Unless the client's stuttering frequency is decreasing (using the average %SS across three within- and three beyond-clinic speaking tasks on three occasions), treatment is introduced after the third pretreatment data-collection session. If stuttering frequency is decreasing, additional data-collection sessions are scheduled at 2-week intervals until speech performance stabilizes.

At the conclusion of the pretreatment phase, participants begin the establishment phase for their assigned treatment program. Regardless of the particular treatment administered, all establishment-phase activities use the same basic structure, encompassing the infrastructural variables known to be associated with the most successful treatment of stuttered speech (Bothe et al., 2006). These include intensive scheduling (3 hours/day, 6 days/week), a sequence of different speech performance tasks of increasing duration, self-management of treatment steps by the client, performance-contingent progress through treatment steps, and stringent speech performance criteria including 0 %SS as the pass criterion at all steps, and the implementation of a requirement for natural-sounding speech indicated by speech naturalness ratings of 1–3 on the 9-point scale introduced by Martin et al. (1984). (Speech naturalness requirements are implemented following the oral reading segment of the program.)

Establishment phases for both programs are organized in five progressively demanding steps (oral reading, monologue, conversation, and two steps of telephone conversation) that each call for three consecutive trials of stutter-free and natural-sounding speech at speaking durations of 1, 2, and 3 min. Self-managed aspects of the treatment require clients to score each trial as including or not including stuttering and to rate their own speech naturalness. When three consecutive trials meet all specified behavioral criteria, the client progresses to the next step. In both programs, an occurrence of stuttering and a speech naturalness rating beyond 3 indicate a failed trial, and the client returns to the first step of that particular treatment task or, after multiple failures, returns to a previous speaking task. Notwithstanding the self-management procedure, the last task at each step (e.g., a final 3-min conversation) must also be judged by the clinician as meeting all applicable speech performance criteria; that is, both programs use self-management of treatment in combination with clinician validation. The duration of the establishment phase is performance dependent and ranged from 3 to 12 weeks for these participants.

During establishment, the treatment targets of the MPI and PS programs are somewhat different (see below); however, the components of treatment that follow are exactly alike for both programs. Participants who successfully complete their assigned establishment phase (see Results) continue to the transfer phase, which requires participants to complete a sequence of three stutter-free and natural-sounding recordings in each of six beyond-clinic settings. These speaking tasks are selected to be relevant to the participant's daily life and are arranged hierarchically. The duration of the transfer phase is again performance dependent and ranged from 10 to 37 weeks for these participants. As in the establishment phase, the first two of the three recordings in a beyond-clinic setting are scored by the client, and the third is scored by the clinician. Participants who complete the transfer phase enter the maintenance phase (Ingham, 1980, 1982, 1999), within which they continue the activities of the last three tasks of transfer. The maintenance phase is accomplished via implementation of performance-contingent increases in the time between assessments, beginning 1 week apart and ending with a 16-week period between assessments. Once again, the client scores two of the three beyond-clinic recordings, and the clinician scores the third. Success with all three recordings enables the client to double the number of weeks before the next maintenance assessment, but failure on any task means that the client returns to the first maintenance phase step. The minimum time to completion is 38 weeks. Actual durations of the maintenance phase for this study were 38 to 78 weeks. Follow-up data are collected from successful participants 1 year after the end of their maintenance phase. Participants who were not successful with the MPI treatment were offered PS treatment and vice versa. Those participants were considered unsuccessful with their first treatment and, therefore, removed from further data analyses and were not followed for the purposes of this study because of the confounding multiple treatments effect (see Results).

The MPI program. Details of the MPI program in terms of its phases, individual treatment steps, and features incorporated in the system software were described by Ingham (1999), Ingham et al. (2001), and Ingham et al. (2013) and are available to interested readers.[3] A brief overview follows. Treatment targets for the MPI program are (a) client-produced connected speech that contains at least a 50% reduction of short PIs (on the basis of the client's shortest quintile range; see Figure 1); (b) 0% SS; and (c) natural-sounding speech. During the establishment phase, the MPI software provides auditory and visual biofeedback of all PI durations. While the client is speaking, the occurrence of a short PI is signaled by an auditory "beep." Concurrently, the computer screen displays two boxes, and a mark appears in the left box for each short PI that occurs; in the right box, marks appear for all other PI durations. The number of short PIs allowed is indicated on the screen as well. If that number is exceeded, the computer stops the progress of the program, and the step is repeated. At essentially alternating steps in the program, PI feedback is not provided. Occurrences of stuttering are judged by the client (a self-managed aspect of the program), who stops the progress of the program immediately when a stutter occurs. Speech naturalness is also scored/self-managed by the client at the end of each speaking trial. If self-judged speech naturalness is not within the 1–3 range (Martin et al., 1984), the step is failed and repeated. As stated above, at crucial steps of the program, occurrences of stuttering and speech naturalness are also judged by the clinician. When the requisite number of speaking trials meeting all three criteria has occurred (see above), the program automatically initiates the next step (i.e., performance-contingent progress through treatment steps).

The PS program. The PS program used in this study is identical to a previously published and evaluated program that can be found in Ingham (1987) and Onslow et al. (1996). As previously stated, treatment targets for the PS program are client-produced connected speech that contains (a) 0% SS and (b) natural-sounding speech. During the oral reading part of the establishment phase, tape-recorded models of prolonged speech (see Footnote 3) are presented in a progressive sequence that begins with models of speech at 70 syllables per minute (SPM) and progresses by 30-SPM increments to 130 SPM. At each step of oral reading (i.e., 1, 2, and 3 min), the client first reads in chorus with the tape-recorded model and then reads at the same speech/prolongation rate without the model. After completion of oral reading, only stuttering and speech naturalness are monitored, and clients progress through the treatment steps as described above.

Measures of Speech Performance, Self-Identification, and PIs

Speech performance, self-identification, and PI data were collected for PWS participants at least three times in pretreatment and twice each in establishment, transfer, and maintenance, including at a predetermined phase midpoint and at the end of each of these phases; and at one follow-up point 12 months after completion of the maintenance phase. Members of the control group each completed two data-collection sessions, once at a time referred to as pretreatment and again at a time referred to as the end of transfer, with the timing of those assessments determined by yoking CONT participants individually to their paired PWS (see Participants, above).

Speech performance measures. At each data-collection session, Treatment Evaluation Speaking Tasks (TEST) assessed speech performance and PI data through the use of three within-clinic and three beyond-clinic speaking tasks, each 3 min in duration. Within-clinic speaking tasks included oral reading from a novel (READ), a monologue on a self-chosen topic (MONO), and a telephone conversation

[3]The MPI program is now available as an app for iPad or iPod touch use at http://mpi-stuttering-treatment.com. The PS program manual (Ingham, Moglia, Kilgo, & Felino, 2007), including model recordings, is available as electronic supplemental files and on request from the first author. Readers interested in the MPI software, peripherals, and program details should also contact the first author.

with a research assistant (PHONE). All within-clinic tasks were audiovisually recorded. Beyond-clinic speaking tasks were speaking with a family member or acquaintance (FAMILY), a telephone conversation with a business (PHONE), and a self-selected difficult speaking situation (SELF SEL). For the SELF SEL task, the participant was instructed to "choose a very hard and, for you, a very important speaking task that is able to be recorded and would indicate that the treatment was or was not working." Typical SELF SEL tasks were speaking before an audience and answering their questions, ordering in a restaurant, and making phone calls to strangers. Beyond-clinic tasks were audio recorded with a miniature cassette recorder that was voice activated, but participants were instructed to inform others that they were being recorded. All TEST recordings were completed without performance-contingent feedback, without performance requirements or contingencies, and outside of the treatment location used for the establishment phase.

All TEST recordings were evaluated at the University of Georgia by trained observers who had no direct contact with the participants and were kept masked as to the participant's group, assigned treatment program (MPI or PS), and treatment phase. TEST recordings for the first five MPI participants were evaluated independently by two trained research assistants at the University of California, Santa Barbara, who were also masked to the participant's treatment phase (see Ingham et al., 2001). All recordings were assessed for percent syllables stuttered (%SS), stutter-free syllables spoken per minute (SFSPM), and speech naturalness (NAT; Martin et al., 1984). All measures were made independently by two judges for each recording and according to the definitions and methods available in a standard and freely available audiovisual stuttering judgment training program known as the SMS (Ingham, Bakker, Ingham, Kilgo, & Moglia, 1999). All judges had been trained on the SMS program.

Approximately eight pairs of judges were used to perform ratings at different times throughout the study. Reliability (replicability) of experimental data was assured by using as the data for all analyses the means of the two independent judges' ratings. In addition, all recordings on which the two judges' data differed by more than 10% were identified and re-rated before the experimental data were finalized. In the case of the NAT scores, reratings were made if the judges differed by more than one unit on the 9-point scale.

*Self-identification measures***.** Perkins's (1981; see also Boberg & Kully, 1994) Speech Performance Questionnaire (SPQ) was adapted for this study to create a 3-item measure that addressed the speaker's self-perceptions and self-identification with respect to speech and stuttering. The three items ("*I am now able to speak normally without thinking about controlling my speech*," "*I now feel like a normal speaker*," and "*I now consider myself a stutterer*") were each rated on a 4-point scale with each point defined (*never*, *sometimes*, *almost always*, *always*). The SPQ was presented to the participant as a paper-and-pencil instrument at each TEST evaluation and required less than a minute to complete.

PI measures. PI data were gathered during all within-clinic TEST recordings for all participants using MPI software and an accelerometer housed within a Velcro neckband and wired to a customized preamplifier unit. The software includes preliminary steps for establishing that the accelerometer signal during phonation meets intensity level criteria and that the noise level within the computer system does not exceed prescribed limits. Routine procedures were used following each resetting of the accelerometer to ensure that a predictable speech sequence with a known number of PIs (counting from 1 to 10) registered the correct number of PIs. To further ensure the validity of PI data, six PWS participants and six CONT participants each provided 20 recorded tokens that were analyzed using the PRAAT (version 4.2.07) acoustic analysis program (Boersma & Weenink, 2003) and by the MPI system. In total, 240 PIs were recorded, ranging from 36 to 778 ms according to the PRAAT analysis. The PI duration of 197 intervals (82%) differed between the PRAAT system and MPI software by not more than 20 ms. The remaining 43 intervals showed the following differences: 23 differed by 22–26 ms, and 20 differed by 31–40 ms. The overall mean duration difference was 17.6 ms. The MPI system ignores PIs of less than 10-ms duration, so the accuracy of the PI measures used for this study was considered satisfactory.

Results

Speech Performance and Self-Identification Outcomes of MPI and PS Treatment Programs

Summarized speech performance data for participants who had successfully completed each phase are provided in Table 1 and Figure 2, with additional detail in Figure 3. Table 1 also shows the number of participants who completed the performance-contingent parts of each treatment phase and were therefore eligible to progress to the next phase of the program, and their mean %SS scores for within- and beyond-clinic tasks (TEST assessments) at the conclusion of each phase.[4]

There was no significant difference between the MPI group and PS group within-clinic ($p > .05$) or beyond-clinic ($p > .05$) mean %SS scores at pretreatment. The MPI group displayed significantly higher within-clinic ($p = .008$) and beyond-clinic ($p = .021$) mean %SS scores than the PS group

[4]Recall that TEST data collection was not directly linked to treatment; participants who had passed the final step of a treatment phase would have done so by demonstrating no stuttering and natural-sounding speech in treatment conditions, but TEST data were generalization measures and, therefore, free to vary. One possible confounding effect on the TEST data is that the within-clinic data were derived from audio-visual recordings, whereas the beyond-clinic data were obtained from audio-only recordings. Conceivably, the audio recordings could have caused the SMS raters to "miss" occurrences of stuttering only distinguished by visual features (e.g., Williams, Wark, & Minifie, 1963). However, if that were the case, then it might have been expected that there would have been differences between the within- and beyond-clinic %SS trends in Figure 3. That was obviously not the case.

Table 1. Number (and percentage) of participants who completed each phase of the Modifying Phonation Intervals (MPI) and the Prolonged Speech (PS) treatments, with mean percent syllables stuttered (%SS) from within- and beyond-clinic Treatment Evaluation Speaking Tasks (TEST; Ingham et al., 2001) assessments after each phase.

Variable	*n*	%	MPI within %SS	MPI beyond %SS	*n*	%	PS within %SS	PS beyond %SS	*N*
Pretreatment	17	100	8.6	6.7	10	100	10.5	7.3	27
Establishment	17	100	2.1	2.7	8	80	0.8	1.2	25
Transfer	15	88.2	0.8	0.7	4	40	0.8	0.3	19
Maintenance	11	64.7	0.4	0.5	3	30	1.0	0.1	14
Follow-up	11	64.7	0.3	0.3	3	30	0.6	0.6	14

at the end of establishment, but no differences existed between groups following completion of transfer, maintenance, or follow-up. In addition, it is clear that participants in both groups who completed their respective programs (MPI = 11; PS = 3) achieved a reduction of stuttering to less than 1 %SS. This reduction did not involve reduced speed of speech or unnatural sounding speech. It also occurred in multiple beyond-clinic speaking situations and was an improvement that generally was maintained across time (Figures 2 and 3). By follow-up, however, there was some deterioration in speech naturalness within the PS group (see Figure 3). At follow-up, 12 months after the active maintenance phase had ceased, two participants (both MPI-treated) had zero stuttering on all six within and beyond-clinic speaking tasks (Figure 3). On the self-selected task, 6/11 MPI participants had zero stuttering with all NAT scores below 3. (Most of these tasks involved public speaking before an audience of strangers who also asked questions, a task deemed highly difficult by the participants.)

Participants who completed either treatment also reported changes in self-identification, from modal responses of *never* or *sometimes* feeling “like a normal speaker” at pretreatment to *sometimes* or *almost always* feeling “like a normal speaker” at the end of maintenance and at follow-up, and from “consider[ing]” themselves to be “a stutterer” *always* at pretreatment to only *sometimes* or *almost always* at maintenance (see Table 2). These changes occurred over the complete treatment time of a mean of 159 weeks (excluding data from four participants who were forced to make a temporary break from the program for 4–9 weeks in the transfer phase because of illness), with the mean and the modal self-identification responses both continuing to change after speech performance had stabilized at low levels (compare Table 1 and Figures 2 and 3 with Table 2). There was no significant difference between mean total number of weeks that successful participants in the MPI (M = 155 weeks) and PS (M = 168) treatment programs required to complete their programs.

PIs as Predictors of Treatment Success

Despite the success of the 14 participants described in the previous section (see above and Table 1), almost half (13/27) of the participants in this study failed to complete all five treatment phases. Nine of these may be categorized as treatment failures at various stages: Four of 17 participants originally assigned to the MPI program were unable to meet that program’s requirements (two during transfer and two during maintenance), and five of 10 assigned to the PS program failed to meet its requirements (two could not complete its establishment phase, and three others could not complete transfer). The other four participants who did not complete their treatment programs (two MPI and two PS participants) dropped out for reasons unrelated to the treatment programs (domestic or legal situations, or concerns about the brain-imaging procedure associated with a related study).

To examine whether changes in PIs predicted success in treatment, PI data from the 14 participants who successfully completed the maintenance phase were compared with those from unsuccessful participants. The 11 successful participants from the MPI program and three from the PS program were combined for the purposes of these analyses, because their speech performance was essentially identical through transfer and maintenance and because so few PS participants met the criteria to be included in these analyses.

Figure 4 shows the number of PIs produced per minute in each of the five duration ranges that defined the quintiles (derived separately for each speaker), for each speaking condition and from all three pretreatment TEST occasions. That is, Figure 4 allows visual comparisons of PI durations from later occasions with PI durations from pretreatment by using each speaker’s pretreatment quintiles as the referent. Figure 5 shows the results of statistical tests of differences between mean number of PIs per minute within each quintile range and the variance in PIs per minute within each quintile range. As shown in Figures 4 and 5, during pretreatment speech, the mean number of PIs per minute in the first quintile (Q1, which includes the shortest PI durations and is also the TRPI range for MPI treatment) was higher for participants who were ultimately successful (shown in black in Figure 4) than for those who were ultimately unsuccessful (shown in red). At the end of establishment and continuing into transfer, however, compared to their pretreatment frequencies, successful participants typically showed significantly fewer PIs in this range, significantly less within-group variability in this range, or both, as compared with unsuccessful participants. Significant changes in the number of PIs, or in within-group variability, also occurred for some longer duration PIs, especially in the range of durations that had defined the speakers’ fourth quintiles (Q4) during pretreatment. Specifically, comparison of

Figure 2. Mean and range of %SS, SFSPM, and NAT scores from each TEST assessment for successful participants who completed MPI (left) or prolonged speech (PS, right). %SS = percent syllables stuttered; SFSPM = syllables per minute in stutter-free speech; NAT = speech naturalness; TEST = Treatment Evaluation Speaking Tasks (Ingham et al., 2001); MPI = Modifying Phonation Intervals treatment.

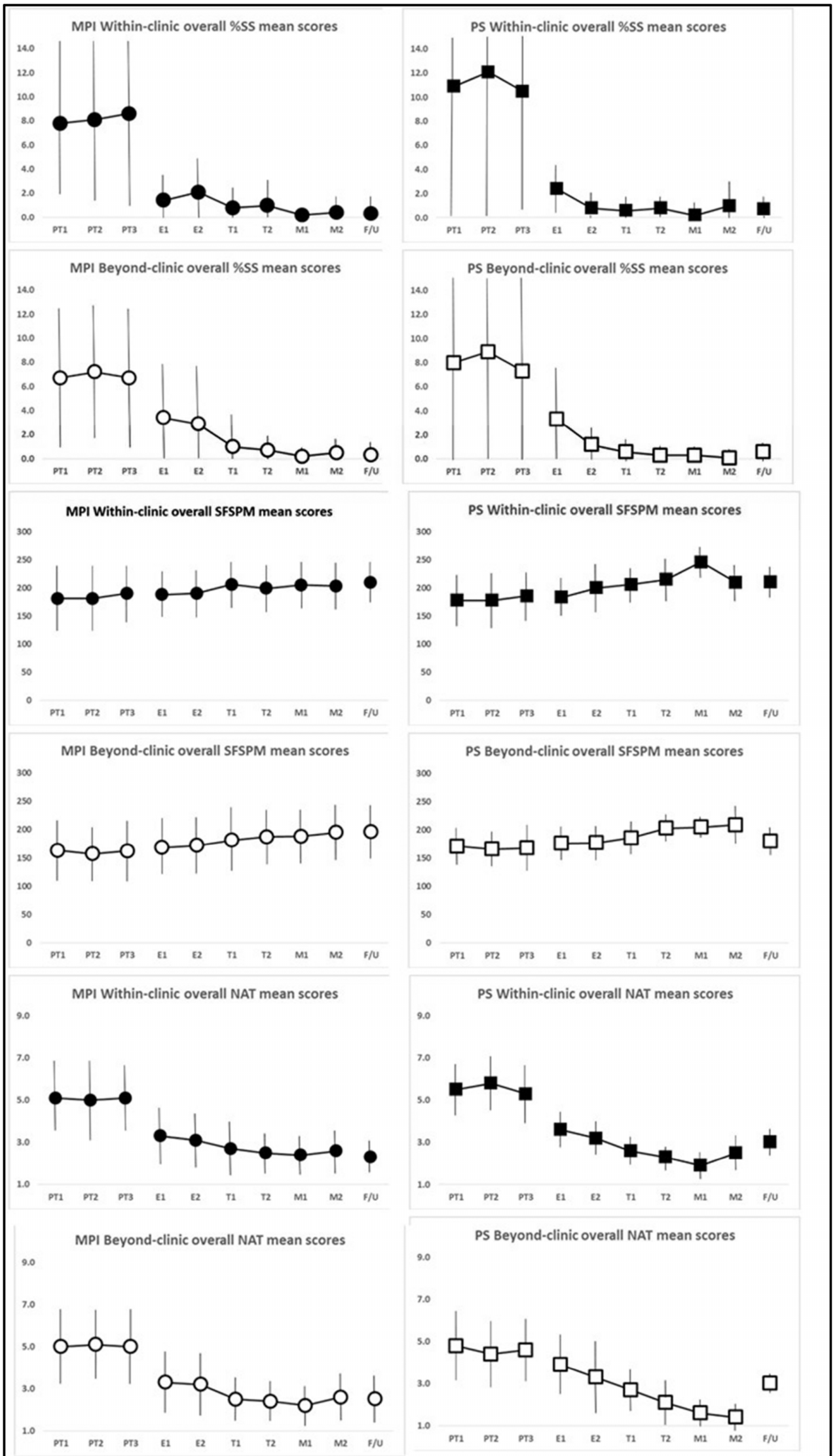


Figure 3. Mean %SS, SFSPM, and NAT scores from TEST assessments (cf. Figure 2), shown separately for three within-clinic speaking tasks (orange = **READ**; blue = **MONO**; black = **PHONE**) and three beyond-clinic speaking tasks (green = **PHONE**; blue = **CONV (family)**; red = **SELF-SEL**). %SS = percent syllables stuttered; SFSPM = syllables per minute in stutter-free speech; NAT = speech naturalness; TEST = Treatment Evaluation Speaking Tasks (Ingham et al., 2001); MPI = Modifying Phonation Intervals treatment.

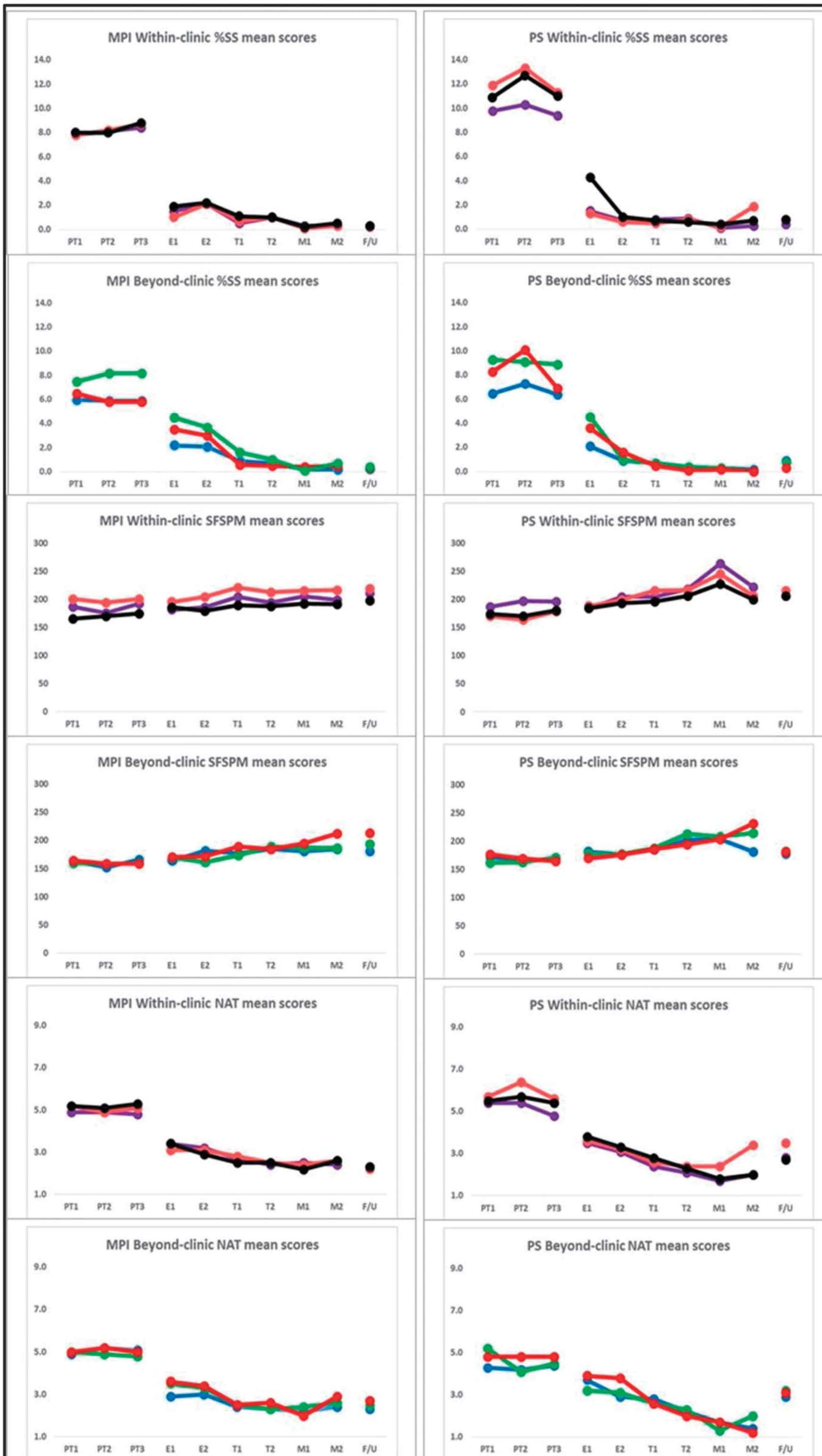


Table 2. Most common response (and range of responses, as text, using N = *never*, S = *sometimes*, AA = *almost always*, A = *always*, unless the mode and range are identical) and mean response (converted to a 4-point ordinal scale where *never* = 0 and *always* = 3) to three items on the Speech Performance Questionnaire at the end of each phase, for each group.

Treatment Phase	MPI	PS	CONT
"I can now speak normally without thinking about controlling my speech"			
Pretreatment	Never/sometimes 0.50	Sometimes (N-S) 0.90	Always (AA-A) 2.88
Establishment	Never/sometimes (N-AA) 0.50	Sometimes (N-AA) 1.63	
Transfer	Sometimes (N-AA) 1.00	Sometimes (N-A) 1.00	Always (AA-A) 2.88
Maintenance	Sometimes (S-AA) 1.25	Almost always (S-AA) 1.67	
Follow-up	Sometimes (S-AA) 1.67	Sometimes/almost always 1.50	
"I now feel like a normal speaker"			
Pretreatment	Never (N-S) 0.42	Sometimes (N-AA) 0.70	Always (AA-A) 2.88
Establishment	Never/sometimes 0.50	Sometimes (N-A) 1.38	
Transfer	Sometimes (N-AA) 0.83	Sometimes (N-A) 1.25	Always (AA-A) 2.88
Maintenance	Sometimes (S-AA) 1.25	Sometimes (S-AA) 1.33	
Follow-up	Almost always (S-AA) 1.67	Sometimes/almost always 1.50	
"I now consider myself a stutterer"			
Pretreatment	Always (AA-A) 2.92	Always (S-A) 2.60	Never 0.00
Establishment	Always (AA-A) 2.67	Sometimes (S-A) 1.88	
Transfer	Always (S-A) 2.33	Sometimes/almost always (N-A) 1.50	Never 0.00
Maintenance	Almost always (AA-A) 2.25	Sometimes (N-S) 0.67	
Follow-up	Almost always (S-A) 2.00	Sometimes 1.00	

Note. MPI = Modifying Phonation Intervals treatment; PS = Prolonged Speech treatment; CONT = control.

Figures 4 and 5 shows that, for several combinations of speaking condition and TEST occasion from the midpoint of the establishment phase (marked as E1 in the figures) through to the end of the transfer phase, participants who were ultimately successful at completing their treatment program produced more PIs in their pretreatment fourth quintile, produced fewer PIs in what had been their longest (fifth) quintile at pretreatment, or showed significantly reduced within-group variability with a trend toward these differences between the means, as compared with participants who were not ultimately successful.

Comparisons to Control Group

All eight CONT participants produced stutter-free and highly natural sounding speech (NAT < 3) on all within-clinic and beyond-clinic recordings. In addition, there were no significant changes in the CONT group's PI data from their first TEST to their second, which occurred on average 35 weeks later (see Figure 4). As a group, successful treatment participants showed similar speech performance (i.e., means of < 1 %SS and naturalness < 3; see Table 1 and Figures 2 and 3). Two of the 14 successful treatment participants produced stutter-free speech on all within- and beyond-clinic TEST speaking tasks, and eight of the 14 self-rated their speech as natural sounding (naturalness ratings of 3 or less on all six TEST speaking tasks). Clinicians also rated those same recordings within the same range. The small amounts of residual stuttering are consistent with the speakers' self-reports of feeling *sometimes* to *almost always* "like a normal speaker" and also *sometimes* to *almost always* considering themselves to be persons who stuttered (see Table 2).

Discussion

Each of the three questions that were the focus of this study was addressed. In summary, the comparison between MPI treatment and PS treatment showed that participants who completed either program achieved similar and substantial reductions in the frequency of stuttering and

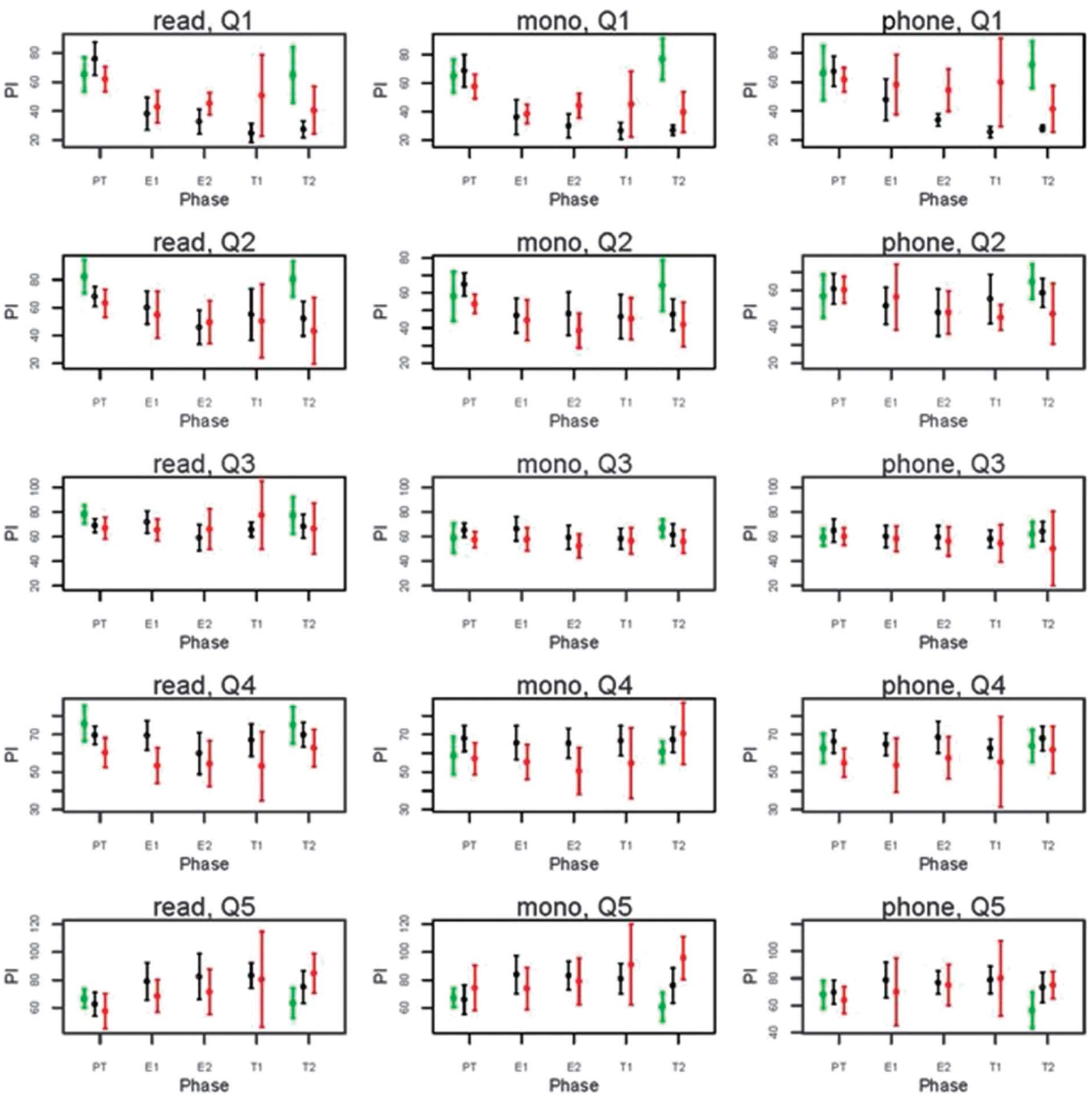
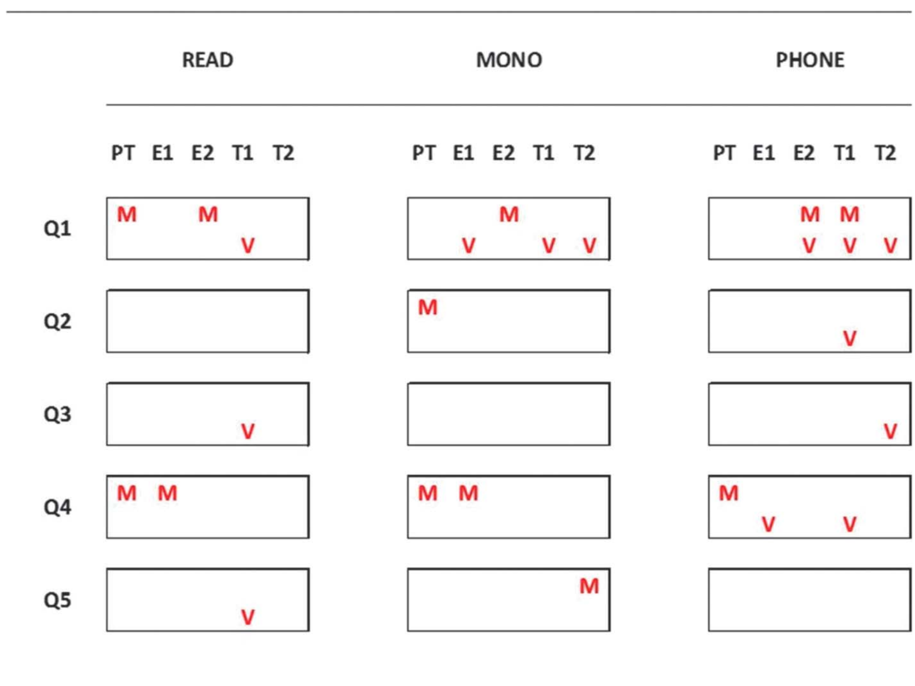


Figure 4. Mean (and 95% confidence limits) number of PIs per minute within the duration ranges that defined the quintiles individually derived for each speaker from pretreatment speech, shown for participants who successfully completed their treatment program (**black**), participants who did not (**red**), and controls (**green**), for within-clinic TEST assessments in READ, MONO, and PHONE conditions at the end of pretreatment (PT), the middle and end of establishment (E1, E2), and the middle and end of transfer (T1, T2). PI = phonation interval; TEST = Treatment Evaluation Speaking Tasks (Ingham et al., 2001); MPI = Modifying Phonation Intervals treatment; READ = reading from a novel; MONO = monologue on a self-chosen topic; PHONE = telephone conversation.

required essentially the same amount of time to complete their programs. All successful participants, from either program, maintained zero or very low stuttering, with speech rates and speech naturalness levels that were similar to those produced by control speakers, throughout extended transfer and maintenance phases that totaled an average of more than 3 years. Successful participants also shifted from viewing themselves consistently as a person who stutters, and as not feeling like normal speakers, to *sometimes* or *almost always* feeling "like a normal speaker." Most speech performance gains were maintained throughout an additional 12-month follow-up period, during which self-identification either stabilized or continued to move further away from "stutterer" and toward "normal speaker."

In short, the speech outcomes of both programs were outstanding and well maintained for successful participants, as has previously been reported for MPI in one preliminary study (Ingham et al., 2001) and for prolonged speech in

Figure 5. Results of comparisons between participants who successfully completed their treatment program and those who did not, for measures of the number of phonation intervals (PIs) per minute within the duration ranges derived by quintile from pretreatment speech (cf. Figure 4). Significant Student *t* tests for differences between the groups' means, where $p \leq .05$, are labeled M; significant *F* tests for differences in the variance, where $p \leq .05$, are labeled V. Student *t* tests were used to compare means between the two groups, and an *F* test was used to compare variances between two groups. A quantile-quantile plot or normal probability plot was used to check the normality assumption (Wilk & Gnanadesikan, 1968). Wilcoxon rank sum test was also applied, and the results remained the same. READ = reading from a novel; MONO = monologue on a self-chosen topic; PHONE = telephone conversation.



many studies and reviews (see Introduction), and these changes were associated with changes in self-image and self-identification.

One major difference between the two treatments, however, was that more than twice the proportion of participants succeeded via the MPI program. This result is also consistent with previous research; the current finding of success for 3/10 adults assigned to the PS treatment approximates, for example, Onslow et al.'s (1996) report that 12/32 of their adult PWS completed the program. The results of this study also provide one possible explanation for this finding. Successful maintenance of stutter-free, natural-sounding speech appears to be associated with both a reduction in the number of very short PIs (those of durations that defined the speaker's shortest 20% at baseline) and also an increase in the use of mid- to long-range PIs, but not the longest (Q4 but not Q5; Figures 4 and 5). MPI treatment requires the first of these changes explicitly, whereas the initial focus of prolonged speech treatments might be described as emphasizing the use of only very long intervals of exaggerated, extended phonation. Thus, participants in MPI treatment may be receiving one of two critical elements directly and efficiently, but participants in PS treatment may be receiving only indirect approximations of the necessary changes that are associated with long-term maintenance of positive treatment outcomes. Those indirect approximations appear to be sufficient for about one third of participants, but the finding from this study—that two PS participants, but no MPI participants, failed to meet performance criteria during the establishment phase—suggests that MPI treatment may be more directly, effectively, and efficiently providing participants with the information they need at initial stages of learning than prolonged speech approaches can do.[5] It remains problematic, however, that four participants who completed the MPI's establishment phase were not successful during their transfer or maintenance phases. Indeed, this failure at a later stage to attain beyond-clinic success, for clients who have achieved stutter-free, natural sounding speech in an initial establishment

[5]Arguably, the use of a biofeedback procedure might have contributed to the differences between the MPI- and PS-treatment outcomes. First, it is important to recognize (see Abstract) that this study was designed to compare a new treatment with the current "standard of care" stuttering treatment for adults, that is, prolonged speech. Second, no attempt was made either in the design or the result analysis to "unpack" the MPI treatment nor to prove that the new treatment was effective because it contained a biofeedback system. We simply wanted to know if it produced a result that was superior to the current standard of care. If we had wanted to test whether biofeedback produced a functional difference between the two treatment programs, then we would have designed an entirely different study.

phase, might be viewed as even more problematic than difficulties that make themselves apparent early in treatment.

This issue is related to questions about relationships among pretreatment performance, immediately posttreatment performance, and long-term outcomes. As mentioned in the Introduction, previous authors have suggested that pretreatment severity and/or immediately posttreatment results might predict long-term performance. For the present study, pretreatment stuttering frequency was not highly predictive of success (the point-biserial correlation between pretreatment stuttering frequency and completion or noncompletion of the maintenance phase as a dichotomous variable was −.096; pretreatment mean stuttering was 7.31 %SS, range 1.06–20.2, for participants who ultimately completed the maintenance phase and mean 9.24 %SS, range 2.08–30.41, for those who did not). Similarly, correlations between pretreatment stuttering frequency and later TEST data were all moderate (r = .571–.580) for postestablishment, posttransfer, and follow-up, and pretreatment and postmaintenance stuttering frequency were unrelated (r = .086) for participants who successfully completed maintenance.

Several notable differences emerged at the end of the establishment phase, however, that point to the importance of clients being able to transfer their skills to nontreatment conditions at that early, or immediately postestablishment, point. Specifically, those participants who would go on to complete the maintenance phase averaged only 0.8 %SS in nontreatment TEST speaking tasks at the end of the establishment phase, whereas those who would prove unable to complete a later phase averaged 3.8 %SS in the postestablishment TEST assessment. In addition, postestablishment stuttering frequency was highly correlated with stuttering frequency at transfer (r = .807). (For later phases, correlations are difficult to interpret because of the reduced range of stuttering frequency scores.) In short, pretreatment stuttering frequency did not predict treatment outcome in this study, but success in transferring stutter-free speech to nontreatment speaking tasks early in a treatment program (i.e., speech performances on TEST tasks) may be critical to clients' ability to continue to manage their improved speech.

Stuttering frequency at maintenance (on TEST tasks), which might be considered the final posttreatment point for these programs, also appears to be highly predictive of stuttering frequency at follow-up, for the participants who successfully completed the maintenance phase. Stuttering frequency for individual participants ranged from 0.0 to 1.6 %SS in maintenance and from 0.0 to 1.3 %SS at follow-up, with seven participants increasing %SS from maintenance to follow-up, seven participants decreasing, and a mean change from maintenance to follow-up of +0.026. This finding is of some interest, in part because it demonstrates that relapse is not inevitable for adults who stutter; successful participants in this study continued to stutter less and continued to view themselves as more typical speakers for a full year after the maintenance program was completed. It has been claimed that allowing a 12-month follow-up evaluation period after the completion of the maintenance phase would allow uncontrolled variables to intrude and confound ultimate outcome data. Such claims may have some face validity (see Ingham, 1981; O'Brian, Packman, Onslow, & Menzies, 2012), and indeed it cannot be said with any certainty that nothing occurred during the follow-up year to influence participants. Nevertheless, the long-term follow-up data are crucial and here serve the very necessary purpose of establishing that treatment gains were maintained after all treatment contingencies and schedules had been removed, something that cannot be measured or determined while treatment is still being administered.[6]

The present results therefore suggest several possible improvements to future treatments for adults who stutter. First, the need to incorporate generalization (Stokes & Osnes, 1989) from the beginning of treatment is reaffirmed by these data; participants who remained successful in the long term were those who could, after only 3–12 weeks of treatment, produce the same essentially stutter-free and natural-sounding speech in multiple beyond-clinic speaking situations (i.e., TEST tasks) that they had learned to produce during therapy. Regardless of the specific treatment approach being used, this emphasis on beyond-clinic work from the beginning of treatment appears to be crucial.

It also appears from these results that the MPI program could be improved by incorporating feedback to the speaker about both a required reduction in very short PIs and a required increase in a specific mid-to-long range of PIs (the fourth pretreatment quintile). Alternatively, the MPI software could be used to focus only on the fourth quintile, a change that might be simpler for clients than the two-quintiles approach and that would essentially be using biofeedback to teach a less exaggerated form of prolonged speech than has traditionally been possible when that speech pattern is taught only by audiotaped or clinician-produced models. Such an emphasis on "longer but not too long" phonation would be consistent with Hillis and McHugh's (1998) demonstrations that biofeedback to reduce the frequency of short pauses or "pauses per minute of acoustic energy" resulted in clinically important benefits with single subjects, a possibility that was never fully explored.

Another set of improvements that might be investigated on the basis of these results arises from the related issues of the time that participants required to complete the entire treatment program and several other features of the overall treatment infrastructure used for both treatments in this study. The mean total time required for successful

[6]We find a logical flaw in the suggestion by O'Brian et al. (2012) that valid treatment outcome data can be derived from evaluations made *during* the conduct of a performance-contingent or other active maintenance schedule. Maintenance phases are a part of treatment, and there is an obvious logical contradiction in claiming to assess the long-term durability of a treatment while the treatment is still being administered. Long-term outcome data must be gathered at a follow-up point well after all treatment, including maintenance phase treatment, has ceased.

treatment, from pretreatment through the end of a successful maintenance phase, was a little over 3 years (159 weeks). Most of the variation occurred, however, in the transfer (10–37 weeks) and especially the maintenance (38–78 weeks) phases; establishment phases were a relatively efficient 3–12 weeks for all successful participants. Much of the reason for this was because participants were permitted considerable latitude in implementing their self-managed schedules during transfer and maintenance. Lacking evidence-based guidelines for implementing self-management, it was decided to simply inform participants that they should complete a scheduled speaking task in the program when they were ready to do so. They were encouraged to proceed through the program at a steady rate while also using self-managed practice, especially during the establishment phase (MPI program participants had access to the MPI hardware through the transfer phase, another variable worthy of investigation). It is not possible to determine from these data, however, whether the approximately 1–3-year duration of focus and practice was necessary to long-term success or whether that time could have been shortened.

Many other variables might be necessary or sufficient for maximizing treatment efficacy, particularly for a behavioral treatment such as the MPI. Many have been explored and investigated by the first author and colleagues (see Ingham et al., 2012). These include identifying functional performance measures (e.g., speech naturalness, speech effort) and endeavoring to integrate them into a performance-contingent management framework. In addition, as brain-imaging research on stuttering has proceeded to search for neural systems that are critical to stuttering, it has become increasingly important to find ways to integrate those research findings with treatment, and especially to guide treatment so as to increase the probability that the known plasticity of the nervous system can be functionally harnessed during treatment (see Ingham, Finn, & Bothe, 2005). With increasing indications that PWS exhibit white-matter abnormalities (e.g., Cai et al., 2014; Chang, Horwitz, Ostuni, Reynolds, & Ludlow, 2011; Cykowski, Fox, Ingham, Ingham, & Robin, 2010), treatments that can be shown to engage neural regions relevant for the change toward fluent speech become a point of considerable interest. Thus, in the course of the present research program, the authors reported (Ingham et al., 2013) positron emission tomography (PET) scan findings indicating that decreases in cerebral blood flow (CBF) in left putamen during the establishment phase are highly predictive of successful progress through later parts of the program, and that CBF increases in left putamen predict just the opposite. The link between these changes and the TRPI frequency is made more plausible for two reasons. The first are the findings reported by Riecker, Kassubek, Groschel, Grodd, and Ackermann (2006), which showed that increases in the frequency of phonated utterances (compatible with improved speech production) in normal speakers are correlated with decreases in CBF activity in left and right putamen. The second, however, seems from the present study's results to be less straightforward. During the period when CBF activity in putamen was decreasing in the successfully treated cohort, there was actually a *decrease* in TRPI frequency. However, PI frequencies outside of the TRPI range (Q2–Q5) showed no such decrease and were accompanied by systematic increases in speech rate. In short, these studies have shown that it may be a combination of TRPI reductions, fourth-quintile PI increases, and reductions in putamen activity that, as a set, could predict within a 12-week establishment phase whether extended self-managed practice in ensuing transfer and maintenance phases will result in successful and durable acquisition of stutter-free, natural-sounding speech. This possibility, and the modifications that need to be made for those clients whose performance at 12 weeks does not meet these criteria, deserves further investigation.

One additional variable that was not systematically investigated within the present study was the amount of self-managed practice that occurred among participants, and especially the amount that differentiated the successful and unsuccessful participants involved in either the MPI or PS program. Informal and frequent comments by participants made it evident that successful participants incorporated substantial and consistent speech practice, usually oral reading, to ensure they could readily produce self-judged stutter-free and natural-sounding speech. Some practice routines appeared to greatly exceed the amount of formal treatment time. The amount of practice time varied greatly, but it was often increased markedly after performance failure caused a retreat within the treatment phase. Practice is a much-overlooked factor in stuttering treatment and warrants formal investigation as to its functional value.

In general, the findings of this study are promising as to adult treatment in general, provide important guidance as to the structure of any treatment, and are especially encouraging of future research on the MPI. There are a number of ways in which the program can and will be improved. Some have already been developed and implemented, including an application for an iPad or iPhone, an automatic server-based data exchange of recordings and treatment status between client and clinician, and incorporation of a system for automatically prompting a client to complete transfer and maintenance phase speaking tasks (Ingham & Student, 2014).[7] The latter system is expected to resolve the problem of slow passage through the program. Finally, the recently discovered prediction of successful passage through the MPI program by using critical neural region change is especially interesting (see Ingham et al., 2013) because it offers the prospect of a more fruitful link between brain imaging and stuttering treatment.

[7] In 2011, a product known as "MPIStutter iPhone App" began to be advertised on the web and purports to be the MPI stuttering treatment program. This product is essentially a crude imitation of just one part of the MPI program and was developed and made available on Apple's App Store without the program author's permission. There is, for example, no performance-contingent schedule of tasks nor clinician-management operations incorporated in this product, features that constitute necessary components of the authentic MPI program.

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