Evaluation of a Stuttering Treatment Based on Reduction of Short Phonation Intervals

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This paper reports the results of an efficacy study of a stuttering treatment program known as Modifying Phonation Intervals (MPI), which trains stuttering speakers to reduce the frequency of relatively short phonation intervals (PIs) during connected speech across speaking tasks and situations. Five young adult male stuttering speakers were treated in this computer-based program that systematically trains speakers to reduce selected short PIs found to functionally control stuttering. The treatment process was evaluated using multiple-baseline designs. Treatment was largely self-managed and based on a performance-contingent schedule of within-clinic speaking tasks (Establishment), beyond-clinic speaking tasks (Transfer), and systematic decreases in assessment occasions (Maintenance). Assessments were made at regular intervals before, during, and after treatment. All speakers achieved stutter-free and natural-sounding speech during within- and beyond-clinic speaking tasks at the completion of Maintenance. All were tested 12 months after completion of Maintenance, and all maintained the results. The findings from this study suggest that this procedure may make a significant contribution to stuttering treatment practice.

KEY WORDS: stuttering, treatment, phonation, outcome, adult stutterers

It is well documented that altering the proportion of phonation during speech will alter the frequency of stuttering (see Ingham, 1990; Wingate, 1976). This occurs most obviously with singing, but it also occurs in conjunction with many other so-called fluency-inducing strategies (see Andrews, Howie, Dozsa, & Guitar, 1982). It is also well established that persons who stutter are relatively slow in initiating and terminating intervals of phonation (see Bloodstein, 1995). There is additional evidence that stuttering is increased during speech that requires the rapid alternation of phonated and nonphonated sounds (Manning & Coufal, 1976) or an increased use of short intervals of phonation (Ingham, Montgomery, & Ulliana, 1983). However, this doesn't necessarily mean that stuttering is *caused* by a fault in the management and production of phonation, because stuttering may actually reemerge among persons who stutter following a laryngectomy (Doms & Lissens, 1973; Tuck, 1979). Nevertheless, the management of phonation does appear to have an important role in controlling stuttering. This paper is the report of an experiment designed to evaluate the efficacy of a treatment based on this principle.

Perhaps the best-known fluency-inducing strategy that emphasizes phonation, other than singing, is the "prolonged speech" pattern. This pattern, which was first described by Goldiamond (1965), appeared in conjunction with the fluency-enhancing effects of delayed auditory feedback (DAF). Over the past 30 years, this speech pattern, or some variant of this pattern, has gradually become a mainstay of the most popular current stuttering treatment programs, especially for adults and adolescents (cf. Curlee, 1999). A drawback of these programs has been that speech at the end of treatment does not sound completely natural, although recent research has shown that the prolonged speech emerging during treatment can be shaped into relatively normal-sounding fluent speech (Ingham & Onslow, 1985). Another well-known drawback is that benefits resulting from treatments using this procedure may require persons who stutter to maintain unacceptable levels of vigilance over their manner of speech production (Cooper, 1984; Howie, Tanner, & Andrews, 1981). In general, there is little knowledge about the components of the prolonged-speech procedure that are functionally important because of the surprising lack of research on this widely used speech pattern.

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, 1984a, 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 intra-clinician 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 employed 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. Similar issues surface in connection with a number of commercial systems such as *Cafet* (Annandale Fluency Clinic, 2000), *Dr. Fluency* (Speech Therapy Systems, 1999), or the *Sustained Phonation Unit* (EZ Speech, 1996) that have been designed to train features related to prolonged speech. As yet, no data have been published demonstrating the effectiveness of any of these commercial systems in a clinical context.

Two data-based procedures based on putative components of the prolonged-speech phenomenon have been investigated for their treatment potential. One procedure, developed by Hillis (1993), has focused on reducing short pauses in the acoustically measured speech of persons who stutter. Computer-transduced feedback of target-range pauses (200–400 ms) is used to train speakers to increase "continuous speechflow." Support for this approach is found among studies by Love and Jeffress (1971) and Winkler and Ramig (1986), who reported a relatively large number of short pauses in the speech of children and adults who stutter. Preliminary experimental treatment studies (Hillis, 1993; Hillis & McHugh, 1998) have shown that reducing these pauses during speech does have promising treatment potential.

A contrasting procedure, developed by the first author and colleagues, emerged from investigations into the effect on stuttering of modifying the frequency of very short phonated intervals (PIs) (Gow & Ingham, 1992; Ingham et al., 1983). In these studies, phonation was operationally defined as an accelerometer- or electroglottograph-detected signal recorded from the throat surface at the thyroid prominence, reflecting vocal fold vibration. The duration of the signal, excluding 10-ms and shorter breaks, formed a PI. The premise underlying these studies was that part of the prolonged speech effect might depend on reducing the frequency of short PIs rather than increasing the frequency of long PIs. Indeed, these initial investigations did demonstrate that reductions in stuttering were associated with decreases in short PIs and that these changes did not necessarily produce unnatural-sounding speech.

The present study evaluates the effects of a stuttering treatment program designed to achieve natural-sounding stutter-free speech by teaching persons who stutter to reduce their frequency of production of relatively short PIs. This program, which is known as Modifying Phonation Intervals (MPI; Ingham, Moglia, Kilgo, & Fellino, 1997), is based on procedures described in the above-mentioned studies by Ingham et al. (1983) and Gow and Ingham (1992). Both of these studies evaluated the effects on stuttering of modifying the frequency of specified PIs during continuous-speaking tasks using a target-range PI feedback system. In the Ingham et al. (1983) study, target-range PIs were recorded via an accelerometer located on the throat near the thyroid prominence, with each target-range PI immediately followed by a brief audible tone. It was demonstrated that stuttering could be increased and decreased in 2 speakers by teaching them to increase or decrease (by at least 50% relative to base rate) the frequency of 10- to 150-ms or 10- to 200-ms PIs. In the Gow and Ingham (1992) study, customized software provided computer-based measurement and feedback of electroglottograph-measured PIs (Fourcin, 1974) and also recorded clinician counts of syllables and stuttering and ratings of speech naturalness (Martin, Haroldson, & Triden, 1984) during speaking tasks by 2 participants. Each speaker's distribution of PIs during base rate was used to identify millisecond intervals that accounted for PI decile ranges (for example, the bottom decile range for one speaker was 30–100 ms and for the other was 15–80 ms). The shortest PI millisecond range that functionally controlled each speaker's stuttering frequency was then determined experimentally in a series of single-subject experiments. Both studies demonstrated that when the frequency of these target-range PIs was reduced by at least 50%, stuttering could also be reduced or eliminated without compromising speech rate or naturalness.

The MPI program has incorporated the previously described procedure for recording and modifying target-range PIs into a four-phase performance-contingent treatment schedule. The four phases, Pretreatment, Establishment, Transfer, and Maintenance, follow a stepwise programmed schedule of speaking tasks that is based on an earlier prolonged-speech treatment schedule (see Ingham, 1980, 1982). Details of the present program have also been described in a recent chapter (see Ingham, 1999). The current paper reports an investigation into the effects of the MPI program by using multiple-baseline single-subject experimental designs with 5 young adults who stutter. This treatment evaluation design is based on a time series evaluation format that has been described and employed in a number of stuttering treatment outcome evaluation studies (cf. Costello & Ingham, 1984; Curlee, 1993; Ingham, 1982, 1993; Ingham & Riley, 1998; Onslow, Costa, & Rue, 1990).

Method

Participants

Five males, aged 18 to 28 years, with histories of chronic developmental stuttering volunteered to participate in this experimental program, the protocol for which had been approved by the University of California, Santa Barbara Institutional Review Board. These were 5 of the first 6 people on a waiting list for treatment. (The 6th moved away before he was able to complete the treatment regimen and is not, therefore, included here.) Participants had received a variety of treatments during childhood, including in one case a program that emphasized prolonged speech; but none had received treatment within the past 8 years. English was the second language for 2 speakers (S2 and S3). When assessed before treatment during monologue tasks, stuttering frequency across speakers ranged from approximately 20 percent syllables stuttered (%SS) to 4 %SS. All showed immediate reductions in stuttering during preliminary assessments using chorus reading, rhythmic speech, and whispering. All had hearing within normal limits. Normal cognitive skills were assumed because all were functioning well in high school or university undergraduate or graduate programs.

Overview of the MPI Program

The MPI program is based on software developed in Windows format operating on a Pentium-based PC computer. Peripherals included an accelerometer[1] and a preamplifier. The accelerometer is housed within a velcro neckband and is wired to a customized preamplifier unit connected to the computer. Built into the program are 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. During speaking trials, the MPI system records all PIs from the surface of the speaker's throat via the accelerometer and provides immediate auditory and visual (bio)feedback to the speaker regarding counts of PIs within particular ranges. Complete treatment schedule details incorporated in the system software are outlined in Ingham (1999).

The MPI Stuttering Treatment Schedule

The MPI treatment schedule is divided into four phases: Pretreatment, Establishment, Transfer, and Maintenance. The clinician directs the Pretreatment phase. The subsequent phases are largely self-managed by the stuttering speaker in conjunction with the computer program, but completion of the culminating steps within each phase requires clinician validation.

Treatment Evaluation Speaking Tasks (TESTs) and Measures

To examine changes in a speaker's performance as a result of the MPI treatment, within- and beyond-clinic Treatment Evaluation Speaking Tasks (TESTs) were

[1] An accelerometer was favored over an electroglottograph because it is less vulnerable to false positives from head movements and swallowing. To further reduce false positives, the millisecond range associated with non-speech-related PIs was ignored. This range was determined individually for each speaker and was generally around 30 ms and below. The validity of accelerometer-measured PIs was estimated from a comparison between the measured PI duration from the MPI program and a spectrographic measure of vowel duration for 29 tokens. There was a mean 5.5% difference between the two sets of measures. For 22 of 29 tokens, there was a difference of 20.4 ms or less between the measures. The most extreme differences were 80.7 and 66.7 ms.

scheduled at 2-week intervals during Pretreatment and at specified steps during Establishment, Transfer, and Maintenance. All TESTs were completed without performance-contingent feedback. Table 1 summarizes the within- and beyond-clinic TESTs, including the measures acquired from each. These measures incorporate the minimum recommended for stuttering treatment evaluation (Curlee, 1993; Ingham & Riley, 1998).

Within-Clinic TESTs

During each within-clinic TEST session, speakers were audiovisually recorded on a Hi-8 video recorder (SONY EV-S3000) in a sound-treated room while they completed the nine speaking trials. During the three Reading tasks, speakers read aloud from *Dead Languages* (Shields, 1989), and for the three Monologue tasks, they spoke on self-selected topics. For the three Telephone tasks, speakers used a telephone in the treatment room to speak with various speaking partners. During all tasks, the speakers sat before a camera and a computer monitor and wore a lapel microphone and a velcro neckband housing the accelerometer. The experimenter was outside the room and managed the session via the master computer (with a link to the speaker's computer monitor) and an intercom.

Research assistants, trained using Stuttering Measurement and Assessment Training (SMAAT; Ingham, Cordes, Kilgo, & Moglia, 1998), used the Stuttering Measurement System (SMS; Ingham, Bakker, Kilgo, & Moglia, 1999)[2] to obtain all speech measures. Used in conjunction with each other, these programs trained judges to identify and count perceived stuttered events (including their duration) and syllables in real time using a computer mouse button. Along with the measures listed in Table 1, the SMS also converted these counts to stuttered and nonstuttered intervals (5-s duration) and collected judges' speech naturalness ratings(at 30-s intervals).

Beyond-Clinic TESTs

These were audio recordings of the speakers in three routine speaking conditions selected individually (see Table 2). For all speakers, Task 3 was chosen because it was an especially problematic speaking activity. Speakers were provided with audiocassette recorders, a supply of tapes, and instructions on arranging and making suitable recordings. Except for the PI data, the measures acquired were the same as those obtained for the within-clinic TESTs (see Table 1).

[2] This system is also available as separate software. It is known as the Stuttering Measurement System (Ingham, Bakker, Kilgo, & Moglia, 1999) and is freely available on request or by downloading the software from the first author's home page at http://speech.ucsb.edu/

Table 1. Within- and beyond-clinic Treatment Evaluation Speaking Tasks (TESTs) and data measures. Data were obtained from 3 min of talking time in each task.

Within-clinic TESTs (prescribed)	Beyond-clinic TESTs (self-selected)
Speaking Tasks; Recording Conditions	
Reading: 3 oral readings; audiovisual	Task 1: one audio
Monologue: 3 monologues; audiovisual	Task 2: one audio
Telephone: 3 telephone conversations; audio-visual	Task 3: one audio
Measures Obtained	
%SS	%SS
SFSPM	SFSPM
Na (assessed for each 30 s of speech)	Na (assessed for each 30 s)
TRPI	—

Note. In conversation samples, single-word utterances were not counted unless they were stuttered, because such counts distort speech rate. Speaking time was derived by excluding nontalking periods of 1.3 s or longer.

%SS = percent syllables stuttered; SFSPM = stutter-free syllables per minute; Na = speech naturalness ratings; TRPI = target range phonation interval counts.

Table 2. Speakers' self-selected beyond-clinic Treatment Evaluation Speaking Tasks (TESTs). Data were obtained from 3 min of talking time in each task.

Speaker	Task 1	Task 2	Task 3
1	Conversation (at home with wife and friends)	Telephone (calls to unfamiliar persons at local stores)	Oral reading (before a graduate seminar)
2	Oral reading (at home with family)	Conversation (with class friends)	Telephone (calls to unfamiliar persons at local stores)
3	Conversation (at school with friends)	Telephone (calls to friends)	Telephone (calls to unfamiliar persons at local stores)
4	Conversation (at school with friends)	Conversation (regular meetings with advisor)	Oral presentation (formal seminar presentations on research)
5	Oral reading (at school with 2- to 3-person audience)	Conversation (at school with friends)	Telephone (calls to unfamiliar persons at local stores)

Note. %SS = percent syllables stuttered; SFSPM = stutter-free syllables per minute; Na = speech naturalness ratings.

Treatment Phases and Experimental Evaluation Format

The general treatment format for this study used performance-contingent schedules within each phase; the effects of treatment were evaluated by using multiple baselines across participants and across speaking tasks (Kazdin, 1998). The procedures for each phase are described below.

Pretreatment Phase

This base-rate phase was conducted by obtaining within- and beyond-clinic TESTs once every 2 weeks. The aims of these sessions were to (a) establish reasonably stable speech performance in within- and beyond-clinic speech samples and (b) identify each speaker's target-range PI. This procedure involved four to eight sessions across the 5 speakers to meet the requirements for an across-subjects multiple-baseline design (S1 = 8; S2 = 4; S3 = 5; S4 = 6; S5 = 7).

Each speaker's target range phonation interval (TRPI) was identified empirically using the MPI program. From the within-clinic TESTs, the MPI program collected all PIs in the 10- to 1,000-ms range and then ranked them, based on their duration, in order to identify the frequency per minute of a speaker's PIs that fell within each 20th-percentile range (in milliseconds). The program permits all PIs recorded within a specified millisecond range to be displayed to the speaker in real time (<0.1-s delay) via a computer terminal display and/or an audio signal. In this manner, the MPI program provided the feedback necessary to help the speaker achieve a minimum required 50% reduction in the PIs produced in the lowest 20th-percentile range identified in the Pretreatment Phase tasks. (Preliminary exploration indicated that few speakers were able to control the occurrence of PIs that fell within their 10th-percentile range.) Therefore, if a speaker averaged 16 PIs per minute in the lowest 20th-percentile range during Pretreatment, then the allowed TRPI frequency would be 8 or fewer per minute. The TRPI selected for each speaker's treatment program was the lowest 20th percentile that the speaker could sufficiently reduce that was accompanied by the elimination of stuttering (see Appendix). Table 3 shows the target PI range (in milliseconds) for each speaker and the maximum allowable frequency of TRPIs per minute for each speaker.

Establishment Phase

After the TRPI was identified, MPI training to reduce TRPI frequency was introduced. While the participant was speaking (with the accelerometer in place), a monitor screen displayed three boxes that showed each PI that occurred as a small colored square with numerical totals above each box. The boxes were configured so the left box displayed PIs that were below the TRPI range, the middle box displayed TRPIs, and the right box showed PIs above target range.

Table 3. Each speaker's PI target range plus the maximum number of TRPIs that that each speaker was permitted to produce per minute during the Establishment phase training. The maximum number of TRPIs per 3 minutes is shown in parentheses (this corresponds to the ceiling level for each speaker, as shown in Figure 3).

Speaker	PI target range (ms)	Maximum TRPIs / min	TRPIs / 3 min
1	28–102	15	45
2	30–148	24	72
3	34–134	15	45
4	32–128	10	30
5	27–150	6	18

The aim of the Establishment phase was to instate stutter-free, natural-sounding speech within the clinic by reducing by at least 50% the frequency of TRPIs. Participants were taught to meet self-rated and clinician-verified speech performance criteria on a series of speaking tasks. The performance-contingent format of this phase (and subsequent phases) has been previously outlined (see Ingham, 1999). Briefly, participants spoke in 1-, 2-, and 3-min trials and were required to achieve a cumulative sequence of 3 successful trials with TRPI feedback (via response-contingent auditory signals and counts in the boxes) and then a sequence of 3 consecutive trials without TRPI feedback. This procedure was followed across a hierarchy of speaking tasks: reading alone, reading with another person present, speaking in monologue alone, speaking in monologue with another person present, conversing with another person present, and conversing on the telephone. Each set of tasks was completed only when a sequence of three 3-min trials was completed successfully *without* TRPI feedback. If the allowable TRPI count was exceeded, the program would automatically fail the speaker and return to an earlier step to be repeated. At the end of each trial, participants scored themselves as having stuttered or not stuttered and rated their naturalness on the 9-point speech-naturalness scale. To progress, each trial had to be self-judged as stutter free and natural (1–3 rating). In addition, successful completion of the sixth and final step in sections where a listener (clinician) was present required the clinician to agree that the trial was stutter free and natural sounding.

The Establishment phase program was conducted during daily or bi-daily sessions lasting 2–3 hours. Most participants completed this phase over 2–3 weeks.

Transfer Phase

The aim of this phase was to shift within-clinic treatment gains to beyond-clinic speaking conditions. In this phase, each participant's individualized beyond-clinic TESTs (see Table 2) were integrated into the treatment. The hierarchy arrangement that applied in Establishment was also fundamental to Transfer. Participants were required to complete a sequence of three stutter-free and natural-sounding recordings (see Table 1) of Task 1, followed by Task 2, and then Task 3. No more than one attempt could be made on a given day. The third recording in each sequence also had to be judged by the clinician as meeting the performance criteria.

Throughout the Transfer phase, participants were permitted access to the MPI program in the clinic for purposes of practicing skills attained during Establishment. Nearly everyone took advantage of this "extra practice" opportunity, but to varying degrees. (The amount of MPI practice time varied from none to 2 hours per week and averaged approximately 25 minutes per week across participants.) An average of 8 weeks was required for completion of Transfer.

Maintenance Phase

The aim of this phase was to facilitate continuation over time of each speaker's previously achieved treatment gains. The performance-contingent maintenance schedule used in this phase was based on procedures previously demonstrated to increase the probability of maintained treatment benefits (Ingham, 1980, 1982). Essentially, participants continued the Transfer phase speaking tasks with performance-contingent increases in the time between those tasks. An entire set of beyond-clinic TESTs had to be judged stutter free and natural sounding in order to extend the number of weeks before the next assessment occasion. Failure at any occasion meant a return to the initial step. Maintenance was regarded as complete when the target behavior had been maintained over two occasions separated by 16 weeks. In effect, speakers had to demonstrate that they could consistently maintain the target behavior for a minimum of 38 weeks following completion of the Transfer phase (22 weeks on the schedule in Ingham, 1999, plus an additional 16 weeks). Across the 5 participants, 12–19 months were required for completion of the Maintenance phase.

Experimental Evaluation Format

In this study, evaluation of treatment efficacy was established first by examining both treatment process and treatment outcome. The effects of the treatment process, that is, the function of the MPI and its phase changes in producing immediate changes in the major dependent variables, was determined by employing a multiple-baseline design across participants and across speaking tasks. Treatment outcome was examined by investigating the role of MPI treatment phase changes in producing clinically important corollary or generalized effects on additional dependent variables and on speech in beyond-clinic situations. These evaluation design features are explicated in the *Results* section.

Measurement Reliability

Observer agreement data were obtained by 3 independent judges who had been trained on the SMAAT and SMS systems and who (among them) rescored, in random order, a total of ninety 3-min samples, 9 within- and 9 beyond-clinic recordings for each speaker. Four recordings were obtained from Pretreatment and 5 from Establishment. The mean %SS, SFSPM, and Na scores from the research assistants and independent judges are displayed in Figure 1, which shows that the "treatment effect" data trends that are evident in the research assistants' scores were mostly preserved within the independent judges' scores. Table 4 shows the summary of the direct comparisons between the total %SS, SFSPM, and Na scores of the research assistants, who collected the original data, and independent judges. A 2-tailed t test showed their scores on each measure were not significantly different (all $p > .3$).

Results

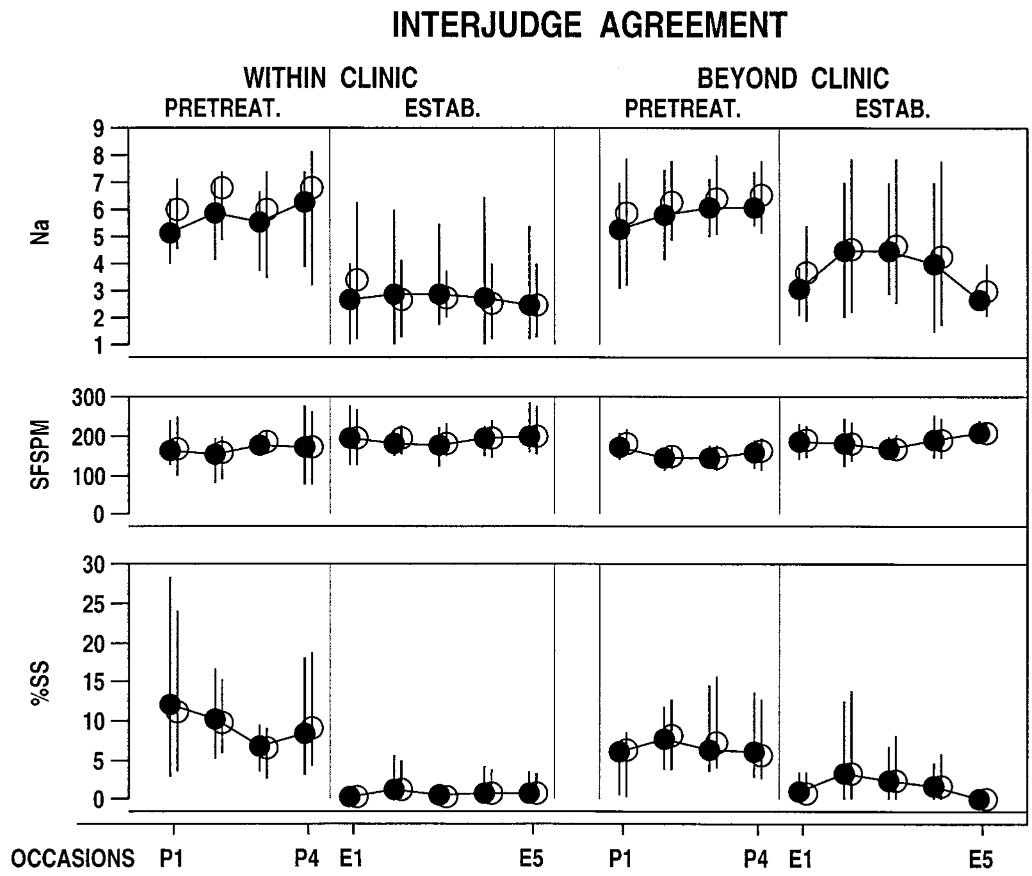
Treatment Process

A multiple-baseline design across speakers and speaking tasks was used to evaluate the effects of the treatment process within this study. For purposes of illustration, the multiple-baseline across-subjects component is demonstrated in Figure 2, which presents the effects of the introduction of the MPI on reading, the first component of the program. (Further description of the findings for reading is reserved for Figure 3, where

Table 4. Mean speech performance scores by research assistants and independent judges on ninety 3-min samples drawn from the Pretreatment and Establishment phases from the 5 speakers. Maximum differences between research assistants' and independent judges' scores for 90% of samples are also shown.

Measure	Research assistants' mean scores	Independent judges' mean scores	Difference between scores for 90% of samples
%SS	4.2	4.2	<1.2
SFSPM	176.8	180.3	<11.9
Na	4.4	4.8	<1.6

Figure 1. Graphically depicted interjudge agreement for speech performance measures. Scores were derived from ninety 3-min samples obtained from a random selection of 4 within- and beyond-clinic TESTs during Pretreatment and 5 within- and beyond-clinic TESTs during Establishment. The closed circles show the mean scores for the research assistants and the open circles for the independent judges. The range of scores (from the highest to the lowest) across the 5 speakers is shown via vertical lines.



they are appropriately integrated into the context of the complete study.) Generally stable baseline (Pretreatment) measurements of %SS, SFSPM, and average naturalness ratings were obtained at 2-week intervals, and each participant was represented by a longer baseline than the previous participants. Particularly for Speakers 2, 3, and 4, changes in the dependent variables occurred only after the introduction of treatment, irrespective of the length of baseline, thus illustrating and replicating across participants the experimental control exercised by the introduction of the MPI. In the case of S1 and S5, the effects were less decisive. During baseline, S1 displayed low %SS scores, but during Establishment he achieved consistent stutter-free and natural-sounding speech (Na < 3) that did not occur during any baseline reading tasks. S5's baseline %SS did show a trend toward reduced stuttering, but over the last 6 weeks of baseline these scores stabilized at ~2.5 %SS. After MPI treatment was introduced, his oral reading was stutter free and his speech naturalness was within the range common to normal speakers (Schiavetti & Metz, 1997). Thus, internal validity was established by demonstrating the positive effects of MPI treatment on reading, replicated across participants.

The multiple-baseline across-subjects design was combined with a multiple baseline across speaking tasks to further examine the role of the MPI in relation to observed behavior changes. This aspect of the experimental design is illustrated in Figure 3, which shows, for each individual speaker, the frequency of stuttering and TRPIs during Pretreatment, Establishment, and Maintenance across Reading, Monologue, and Telephone speaking tasks. The dashed vertical line indicates that treatment was introduced sequentially across these three tasks; that is, E1 data points were obtained at the completion of Reading, E2 data points at the completion of Monologue, and E3 data points at the completion of Telephone conversation, which was the last step in the Establishment phase. E3 data, then, reflect the full effects of the treatment process.

Figure 2. Individual participant findings are reported for percent syllables stuttered (%SS), stutter-free syllables spoken per minute (SFSPM), and naturalness ratings (Na, 1 = highly natural; 9 = highly unnatural) obtained from reading TESTS obtained at 2-week intervals during Baseline (Pretreatment) and at the completion of MPI treatment for Reading, Monologue, and Telephone treatment steps during Establishment. The broken vertical line indicates the end of baseline (progressively longer for each speaker) and the introduction of MPI treatment, illustrating the multiple-baseline across-subjects design.

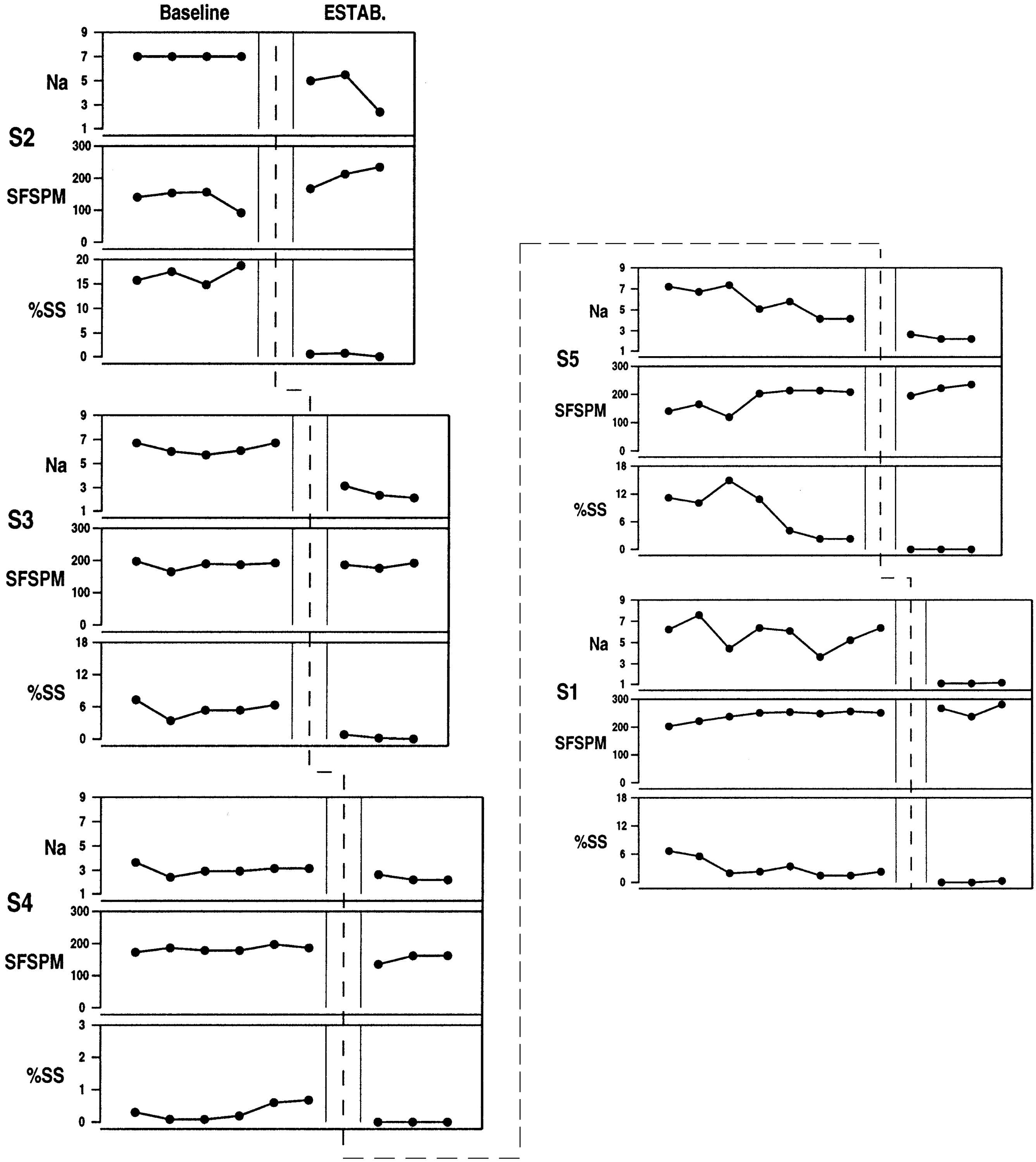


Figure 3a. Subject 1. Treatment process results as reflected in the measurement of the frequency of stuttering (stuttered events) and the frequency of target range phonation intervals (TRPIs) are shown for each speaker in a multiple-baseline experiment across speaking tasks. Each speaker's figure shows the within-clinic TEST results for 3-min samples in Reading, Monologue, and Telephone during 3 occasions within the Pretreatment and Establishment phases and one occasion within the Maintenance phase. Participants completed a different number of TESTs in each phase. Partial results are shown: for Pretreatment, the initial, middle, and final TESTs (P1, P2, P3, respectively); for Establishment, TESTS administered at the completion of reading, monologue, and telephone TRPI treatment (E1, E2, E3, respectively); for Maintenance, TESTs obtained at the second measurement occasion (M2), 12 weeks following the completion of Transfer. The broken vertical line shows when MPI training was introduced for Reading, then Monologue, and finally Telephone tasks. The horizontal broken line in the Establishment and Maintenance phases shows the target frequency for the TRPIs.

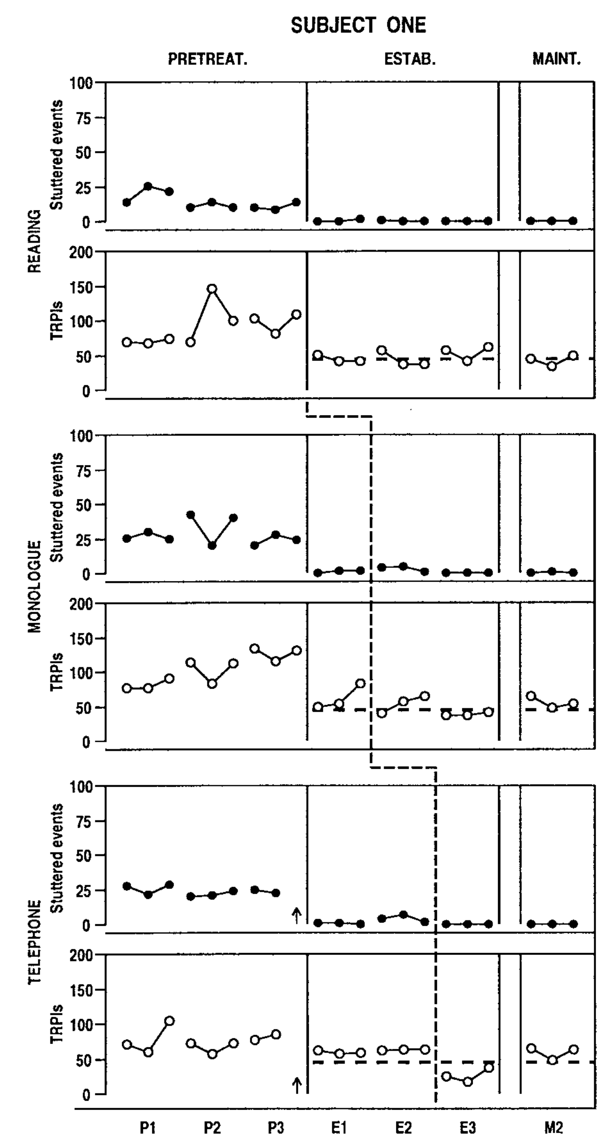
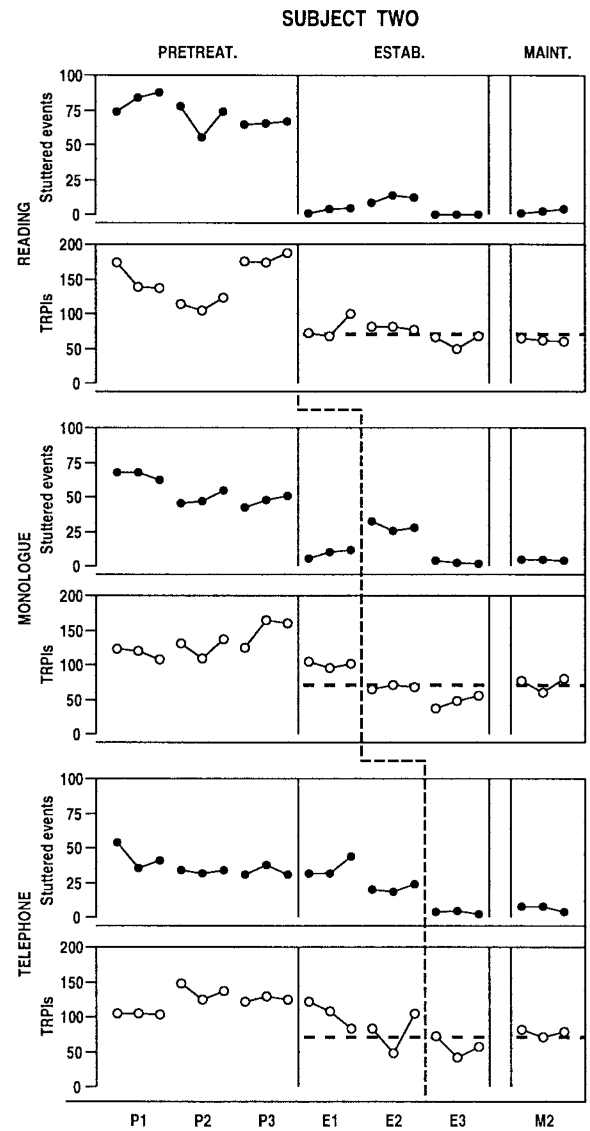


Figure 3b. Subject 2.



The process analysis was designed to explore the relationship between the frequency of TRPIs and stuttering, so fundamental to the rationale underlying the MPI treatment. Measurements were made during the within-clinic TESTs in the Pretreatment and Establishment phases, plus a brief additional assessment partway through Maintenance. Because all speakers completed the Establishment phase successfully, it follows that they met the TRPI, stuttering, and naturalness criteria for each step within that phase. This is obviously a direct test of treatment process effects, but one that is colored by the presence of treatment contingencies. Therefore, an independent test of the treatment was made with data from the within-clinic TESTs that were conducted periodically during the Establishment phase, without TRPI- or stuttering-contingent feedback.

Figure 3c. Subject 3.

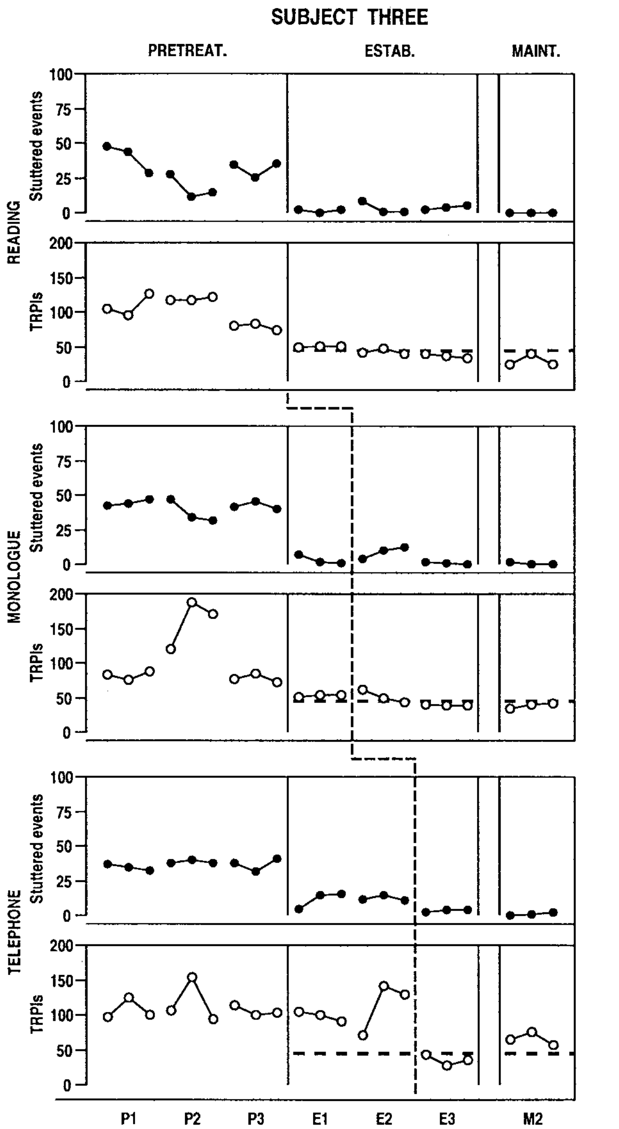
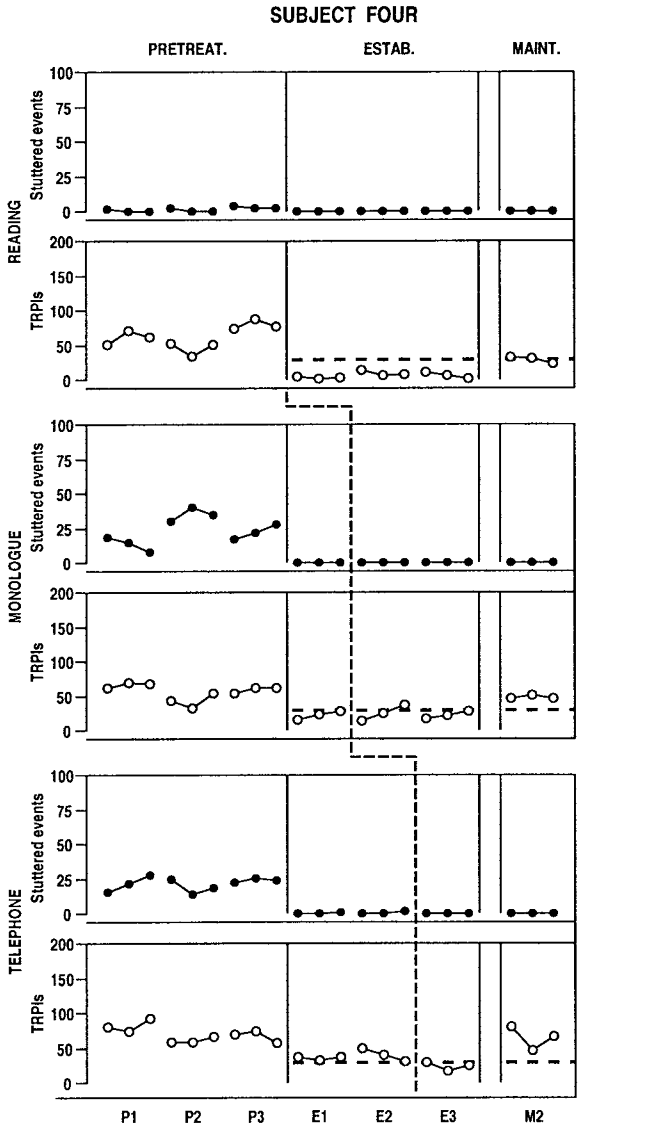


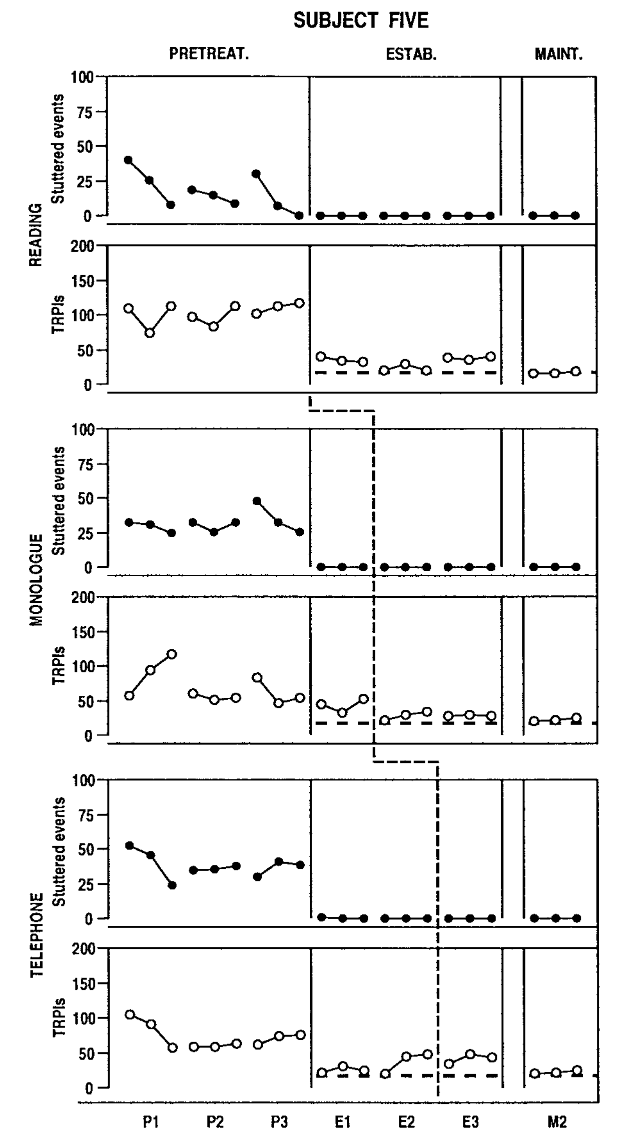
Figure 3d. Subject 4.



In order to make data presentation less cumbersome (but at the same time obscuring the multiple-baseline across-subjects aspect of the design—hence Figure 2), data for each speaker are collapsed as follows. The three data points presented within Pretreatment were the first, middle, and last TEST sessions for each speaker. In Establishment, the first, second, and third data points identify the findings at the time that each speaker completed oral reading (E1), monologue (E2), and telephone (E3) treatment steps. Data from the maintenance condition are shown from TEST occasion M2, which occurred approximately 12 weeks after the beginning of that phase. Each within-clinic TEST during these phases provided three 3-min reading, monologue, and telephone trials. Consequently, data to evaluate the effect on stuttering of modifying PI frequency were available from nine 3-min Pretreatment and Establishment trials and three 3-min Maintenance trials. Figure 3 also shows for each speaker a horizontal line in the Establishment and Maintenance phases that corresponds to that speaker's maximum allowable TRPI count for 3-min trials (see Table 3).

The positive effects of TRPI treatment on the Reading task are generally immediate and consistent throughout the Establishment phase. In all participants, TRPIs were reduced, typically near the 50% level. For 3 speakers, stuttering reduced concurrently. The exceptions were S4, who displayed very little stuttering during Reading, and S5, who showed a declining trend of stuttering during Pretreatment. The effect of shifting the treatment to Monologue was not apparent in any speaker, largely because the Reading treatment also immediately reduced TRPIs and stuttering frequency

Figure 3e. Subject 5.



in the Monologue tasks. However, evidence of a replication of the effect of TRPI treatment occurred when it was shifted to the Telephone tasks, and further reductions in TRPIs and stuttering frequency occurred for Speakers 2 and 3. (The others had already generalized from the effects of Reading treatment.) During the last 3 data points in the Establishment phase, it is clear that the criterion level for TRPIs was achieved for almost all speaking tasks and, as well, stuttering was reduced to near zero in all tasks. It is also of interest that these changes were generally sustained during the subsequent Maintenance phase. Additionally, these effects were replicated across all 5 speakers. In summary, although experimental control was not perfectly reflected in these performance measures, for the most part the data trends do show that the TRPI frequencies exerted a considerable level of functional control over each speaker's frequency of stuttering.

Treatment Outcome

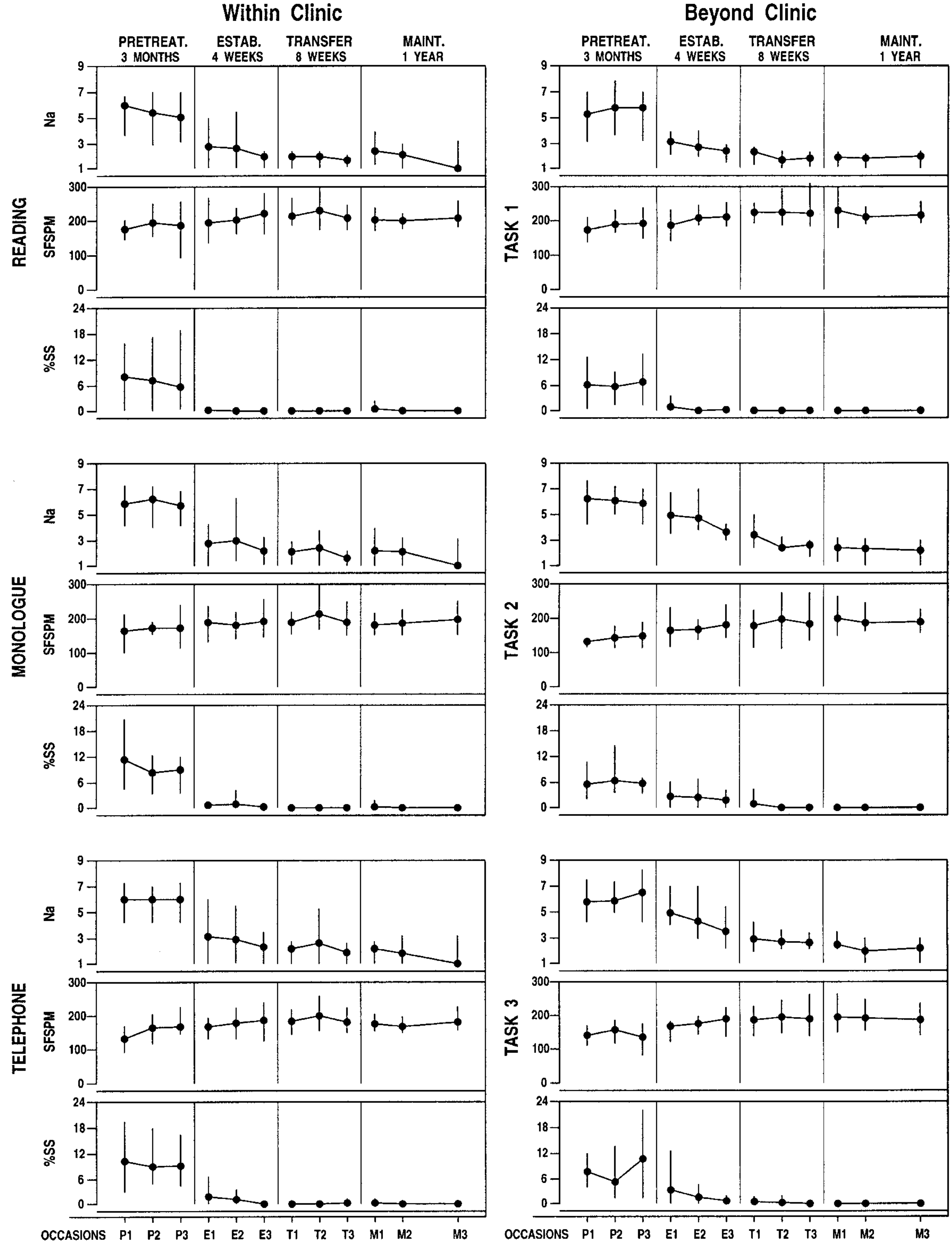
The effect of the MPI on stuttering, speech rate, and speech naturalness over the entire course of the treatment program was evaluated within the above-described multiple baseline across participants and speaking tasks. As described above, speakers were assessed on the within- and beyond-clinic TESTs on at least 3 occasions within each experimental phase (Pretreatment, Establishment, Transfer, and Maintenance) as depicted in Figure 4. This figure shows a composite presentation of the mean %SS, SFSPM, and Na scores for the three within-clinic TESTs (left panel; Reading, Monologue, and Telephone tasks) and the three beyond-clinic TESTs (right panel; self-selected speaking tasks) across all 5 participants. In addition, the range of scores, from the highest to the lowest, is shown for each evaluation occasion. The three data points presented for Pretreatment, Transfer, and Maintenance were the first, middle, and last TEST session for each participant (TESTs ranged from 4 to 12 within phases); for Establishment, successive data points identify when participants completed Oral Reading (E1), Monologue (E2), and Telephone (E3) treatment, respectively (see Method). The length of the phases within Figure 4 differed across participants and across the 4 phases. (The mean phase length time is shown above each phase in Figure 4).

The results are generally straightforward. For the within-clinic TESTs, %SS scores declined from Pretreatment to Establishment. In fact, as previously shown in Figure 3, by the completion of Reading treatment (E1), stuttering was reduced to zero for all speakers in the within-clinic reading task, and a substantial reduction in stuttering occurred concurrently on the remaining, as-yet-untreated, within- and beyond-clinic speech samples. Introduction of treatment in monologue and then telephone modalities (E2 and E3) further reduced stuttering essentially to zero across all within- and beyond-clinic samples for all speakers. Further, these near-zero levels of stuttering continued through Transfer and were sustained by all speakers through the Maintenance phase. The reductions in %SS scores were accompanied by slight increases in SFSPM scores, obviating any suggestion that reduced speaking rate accompanied these improvements. As well, Na scores improved progressively and ultimately reached levels (ratings of 1–2) that typify normally fluent speech (see Schiavetti & Metz, 1997).

Discussion

The present study reports the first findings from an investigation of the effectiveness of a stuttering-treatment

Figure 4. Treatment outcome results across the 4 phases of the study (Pretreatment, Establishment, Transfer, and Maintenance) are summarized for the 5 speakers. The left panel shows results for the 3 within-clinic TEST conditions (Reading, Monologue, and Telephone) and the right panel for the 3 beyond-clinic TEST conditions (Tasks 1, 2, and 3). The dependent variables shown are the mean scores for percent syllables stuttered (%SS), stutter-free syllables per minute (SFSPM), and speech naturalness (Na) at each TEST occasion. The vertical line through the mean score shows the range of scores for the 5 speakers. TEST data were derived from 3 occasions within each phase. Speakers completed a different number of TESTs in each phase; only the initial, middle, and final TEST in each phase is shown. The average time (weeks/months) for speakers to complete the requirements for each phase is shown below the phase labels.



program based on training to reduce the frequency of relatively short intervals of phonation during connected speech. Only 5 adults who stutter were evaluated in this study, but the findings appear to provide strong encouragement for a more extensive investigation of the treatment's benefits. All participants displayed evidence that the treatment process was directly associated with reduced stuttering, increased speaking rate, and improved speech naturalness within and beyond the clinic environment. Further, these changes were sustained throughout the Maintenance phase of the treatment program. All participants were also assessed in all beyond-clinic speaking conditions 12 months after the completion of the Maintenance phase and showed levels of performance that were essentially identical to the levels reported at the completion of that phase. In addition, all participants provided personal testimony that the treatment led to major positive lifestyle changes. These statements were corroborated through unsolicited comments received from their close friends and their families. No participant reported being completely free of the need to routinely self-monitor his speech, but none regarded this as a problematic feature of the treatment. They also reported a variety of self-practice regimes throughout the Transfer and Maintenance phases that included periodic practice with the MPI system. These comments were consistent with the participants' responses to Boberg and Kully's (1994) *Speech Performance Questionnaire* (results available on request). Three participants reported on the questionnaire that they now always feel like normal speakers and do not consider themselves to have a stuttering problem.

One important methodological issue concerns determination of treatment efficacy when there is unregulated access to the MPI system. This is an important issue because, arguably, if treated speakers are able to have access to the basic treatment system, then treatment efficacy evaluation data may be confounded because treatment has not ceased. For instance, treatment efficacy evaluations would be rather obviously compromised if participants continued to wear devices such as the "Pacemaster" in the Metronome Conditioned Speech Retraining program (Brady, 1971) or a portable Edinburgh Masker (Dewar, Dewar, Austin, & Brash, 1979) in any evaluations of those treatments. At a less observable level is the formal or informal practice of certain speech patterns that participants may or may not use following the completion of a treatment program (see Ingham, 1984a). In some studies, self-help groups have been formally established to help people maintain improved fluency (cf. Howie et al., 1981). In each instance, these add-on procedures may amount to a continuing active maintenance or treatment program (see Ingham, 1984b). Even a cursory consideration of this issue immediately highlights just how difficult it is to discern the point when a stuttering treatment actually ceases. For instance, treated speakers are always free to engage in self-managed practice regimes that they might compose out of their original treatment program. It could be argued that whenever they do so, they are continuing their treatment—perhaps by necessity in order to sustain the benefits of their treatment. (Relevant here is the fact that the MPI program can now be installed on a home computer, making continuing assistance easily accessible after formal treatment ceases.) Nonetheless, these various strategies may or may not be functionally controlling stuttering; and that is surely a fundamental issue that needs to be resolved with regard to any consideration of their relevance to treatment evaluation.

The present study's experimental design verified the role of the MPI treatment procedure in regard to the measured behavioral changes/outcomes. Previous stuttering-treatment investigations have often failed to establish the functional relationship between the treatment method and the target speech behavior. The notable exceptions to this have been treatments that use contingencies on stuttering, such as time out (e.g., Costello, 1975; James, 1981; Martin, Kuhl, & Haroldson, 1972; Reed & Godden, 1977), and occasionally masking (Block & Ingham, 1984) or biofeedback (e.g., Moore, 1978) procedures. However, similar validations have not occurred in conjunction with the "prolonged speech" treatments, where the specific treatment agents are typically described, rather than verified, as the fundamental component of the treatment strategy. For the most part, the multiple-baseline evaluation in the present study confirmed that reductions in stuttering during the Establishment phase were functionally related to reduced TRPIs. However, there were also some inconsistent relationships between reductions in TRPIs and stuttering (e.g., Figure 3: S4, Telephone; S5, Reading). In short, it is certainly not clear from the present findings that the reduction in TRPIs is the only functional treatment variable within the MPI. Conceivably, changes in TRPIs may have led to the recruitment of other treatment agents (e.g., attentional factors). Finally, the use of a 50% rather than any other percentage reduction in TRPIs remains an unknown variable within the treatment process. Needless to say, additional research is required to establish the most functional percentage reduction.

This treatment report is an interim account of the development of a treatment program. One interesting by-product of the treatment process analysis concerned the broad generalized effect of MPI treatment on reading, which initiated the program (see Figures 3 and 4, E1). Reduced TRPI and stuttering frequency, increased speech rate, and improved naturalness spread across yet-untreated within-clinic monologue and telephone tasks as well as beyond-clinic speaking tasks for most participants. In addition, it appeared that the introduction of treatment during telephone talking polished off the remaining changes required for a completely successful treatment effect during Establishment (see Figure 3, especially Speakers 2 and 3). Obviously, experimental order effects (telephone treatment was the final step in the phase) limit the extent to which firm conclusions are possible; nevertheless, it was clear that stuttering and especially speech naturalness showed maximum improvement across speaking tasks after the telephone task treatment was completed. This finding might suggest that the MPI Establishment phase could be abbreviated if treatment were focused on reading and telephone speaking tasks at an earlier point in the program. In fact, the design of this study, which did not include periodic withdrawals of treatment, did not allow fine-grained analysis of the relative contributions of each segment of the treatment protocol. Clinical experience leads one to believe, for example, that Transfer and Maintenance phases would be critical, but such an assumption was not tested in this study. Studying the individual functional components of this treatment is a goal of future research.

One important feature of this program is that it has been built on a foundation of experimental investigations into each of the treatment procedures. These include the effects of phonation interval frequency modification (Gow & Ingham, 1992; Ingham et al., 1983), modification of speech naturalness (Ingham & Onslow, 1985), a performance-contingent maintenance schedule, and self-evaluation training (Ingham, 1980, 1982). The latter is exceptionally important in considering not only the effect of self-evaluation on generalization, but also the economies of managing treatment. One important benefit of this program that was often mentioned by participants was that they had some measure of control over the progress of treatment. Participants were able to choose when and for how long they would engage in treatment sessions, and they had the responsibility of judging their own stutters and speech naturalness. They selected their own beyond-clinic speaking tasks and obtained and scored their own recordings during Transfer. The initial phases of the treatment involved sessions of 2–3 hours per day for approximately 2–3 weeks, which is a remarkably small amount of clinician management. The exceptions were, of course, the regular scoring of within- and beyond-clinic TESTS and the verification of speakers' stutter-free, natural-sounding speech at the completion of each part of the Establishment, Transfer, and Maintenance phases. However, the speakers essentially managed most of the Establishment phase time following the initial evaluation for target-level PIs. It is also noteworthy that all speakers expressed an enthusiastic reaction to the treatment procedure. Indeed, in some cases it was almost necessary to prevent them from spending more than 4–5 continuous hours of talking time because of concerns about vocal fatigue. The appearance of this strong self-initiative characteristic among participants implies that self-efficacy principles (Bandura, 1977; Prins, 1993) may eventually assist in understanding the operation of the MPI program. At the same time, these findings do not mean that the MPI program offers a panacea for stuttering treatment. Not all participants have shown completely positive benefits; among 20 persons who have been partially or fully treated thus far (in a nonexperimental routine clinical application of the program), the experimenters have encountered 2 participants who failed to respond to MPI treatment.

In summary, the present findings provide strong evidence that one important dimension of the prolonged speech effect, the duration of intervals of phonation, not only may functionally control stuttering but can be used in conjunction with other specified strategies to provide a replicable and testable treatment procedure. It is premature to make any comparison with the findings of related treatment programs. However, the present treatment efficacy findings do provide a strong basis for a more extensive investigation of this procedure with larger and more varied populations of persons who stutter.

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Appendix. Procedure for Initial PI Control Training and TRPI Identification.

Training began with instructions on how the computer-operated audiovisual TRPI feedback system operates. The MPI's TRPI was then set at each speaker's lowest 20th percentile range while the speaker made a series of short and long phonated sounds sufficient to produce some TRPIs and some PIs that exceeded the TRPI. This enabled observation of the operation of the audiovisual display/feedback system on the terminal screen. Speakers then read aloud while trying to reduce the frequency of TRPIs using a self-managed time-out system (e.g., James, 1981). That is, they paused briefly immediately after hearing the TRPI signal (indicating occurrence of a short PI) and then repeated the same word until it did not activate the signal. This practice continued until the occurrence of TRPIs during three consecutive 1-min trials was eliminated. If any TRPI occurred before 1 min elapsed, the trial ceased immediately and the screen displayed "Target Count Exceeded."

Speakers' selected TRPI ranges were then evaluated using a series of ABA trials. Condition A1 (base rate) required completion of three 1-min readings during which PIs and stuttering frequency were free to vary. Condition B, using the TRPI feedback practiced previously, required speakers to complete three consecutive 1-min trials with ≤50% of base-rate frequency. Stuttering frequency was concurrently measured. Condition A2 repeated the A1 condition. If Condition B did not reduce TRPIs by ≥50% *and* stuttering by ≥90%, the TRPI range was expanded from the 20th to the 40th percentile level and the procedure was repeated.