Measurement of Speech Effort During Fluency-Inducing Conditions in Adults Who Do and Do Not Stutter

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Purpose: To investigate the effects of 4 fluency-inducing (FI) conditions on self-rated speech effort and other variables in adults who stutter and in normally fluent controls.
Method: Twelve adults with persistent stuttering and 12 adults who had never stuttered each completed 4 ABA-format experiments. During A phases, participants read aloud normally. During each B phase, they read aloud in 1 of 4 FI conditions: auditory masking, chorus reading, whispering, and rhythmic speech. Dependent variables included self-judged speech effort and observer-judged stuttering frequency, speech rate, and speech naturalness.
Results: For the persons who stuttered, FI conditions reduced stuttering and speech effort, but only for chorus reading were these improvements obtained without diminishing speech naturalness or speaking rate. By contrast, speech effort increased during all FI conditions for adults who did not stutter.
Conclusions: Self-rated speech effort differentiated the effects of 4 FI conditions on speech performance for adults who stuttered, with chorus reading best approximating normally fluent speech. More generally, self-ratings of speech effort appeared to constitute an independent, reliable, and validly interpretable dimension of fluency that may be useful in the measurement and treatment of stuttering.

KEY WORDS: stuttering, speech effort, fluency induction

Normally fluent speech is not easily defined (Finn & Ingham, 1989), but there appears to be some consensus that, as compared with stuttered speech, it is typified by (a) relatively little disfluency, (b) normal utterance rate, (c) natural sounding speech quality, and (d) relatively little effort (Starkweather, 1987). The first three of these characteristics have been studied extensively (see Young, 1994). They lend themselves to objective or observer-judged measurement, and they have also been of some benefit in prescribing some goals for stuttering treatment, describing the outcomes of treatment, and even developing methods for shaping normally fluent speech during some treatments (e.g., Onslow & Ingham, 1987).

Speech effort, in contrast, remains an elusive concept (see Ingham & Cordes, 1997). According to Starkweather (1987), fluent speech can be conceptualized as being "effortless" in two ways: (a) it requires little cognitive preparation and (b) it requires only a small amount of muscular exertion. Correlates of the latter might be measurable in terms of electromyographic activity, but this final characteristic of fluent speech differs importantly from the first three in that it is primarily a self-judgment of a perception, rather than an objective measurement. Both observer judgments and self-judgments have long histories in stuttering research and treatment, and both are affected by similar problems of definition, reliability, and validity (see Cordes & Ingham, 1994; Franic & Bothe, 2008). With respect to both definition and interpretation, for example, previous research has demonstrated speakers' ability to differentiate between how natural their speech *felt* and how natural it *sounded* (Finn & Ingham, 1994); the same participants also used descriptors that referred to either "cognitive effort" or "attention to speech" when asked to identify the features they had used to rate how natural their speech felt. The usefulness of self-ratings of speech effort, therefore, may depend on the extent to which speakers can differentiate between cognitive and physical effort and naturalness. Similarly, Boberg and Kully (1994), in a treatment study with adults and adolescents who stuttered, used Perkins's (1981) Speech Performance Questionnaire to measure self-reported perceptions and performance after treatment. They reported that 29 out of 30 participants felt, 12–24 months after therapy, that they could "almost always" or "sometimes" "speak normally without thinking about controlling speech" (Perkins, 1981, p. 1056). Whether "thinking about controlling speech" is a self-rating of cognitive effort or a self-judgment of physical activity, however, is difficult to determine, despite the acknowledged importance of these constructs to the perceived success or failure of stuttering treatment.

Speech Effort and Fluency-Inducing (FI) Conditions

Ingham, Warner, Byrd, and Cotton (2006) attempted to address directly some of these questions about speech effort ratings by investigating the effect of chorus reading on self-rated speech effort. Twelve persons who stuttered (10 men, all adult) and a sex- and age-matched group of normally fluent controls used a variation of Martin, Haroldson, and Triden's (1984) 9-point Speech Naturalness Scale to measure speech effort, both while they read alone and while they read along with a prerecorded accompanist (chorus reading is a condition known to reduce stuttering). On the 9-point Speech Effort Self Rating Scale used by Ingham et al., responses ranged from 1 (*very effortless speech*) to 9 (*very effortful speech*), with repeated instructions to the participants that they should focus on "physical effort" or the "amount of physical effort needed to speak, whether or not you were stuttering" (p. 663). Ingham et al. reported that the group of persons who stuttered averaged approximately 2.5 on the Speech Effort Self Rating Scale during chorus reading, which was significantly better than their ratings during nonchorus reading (approximately 5.7), but significantly higher than ratings provided by the controls during nonchorus reading conditions (approximately 1.5). One additional finding of interest in the Ingham et al. study was that chorus reading required a significant increase in speech effort by the normally fluent control group. In fact, their level of speech effort during chorus reading was not significantly different from that reported by the group of persons who stuttered during chorus reading. This finding could be interpreted to mean that while a fluency-inducing (FI) condition might produce reduced speech effort in persons who stutter, that only occurs because of reduced stuttering and not because these speakers now also produce more normally fluent speech.

One shortcoming of Ingham et al.'s (2006) study, however, is that it used only chorus reading, rather than testing whether the obtained speech effort levels were characteristic of other FI conditions. The present study was intended, therefore, to expand current knowledge about self-judgments of speech effort by investigating four different FI conditions: auditory masking, chorus reading, whispering, and rhythmic stimulation. All four have been demonstrated to reduce stuttering frequency in adult persons who stuttered (Bloodstein, 1995). They were selected for use in this study because they are suitable for use with oral reading, are amenable to controlled presentation, can be adjusted for individual participants, and also differ from each other in some relevant characteristics, as discussed immediately below.

Masking

Partial or complete auditory masking of the speaker's voice signal is a well-documented procedure for producing a temporary reduction in the frequency of stuttering (Ingham, 1984). Initial demonstrations showed that 90 dB SPL white noise is sufficient to mask the speaker's voice, at least partially, and reduce stuttering immediately (Maraist & Hutton, 1957). Later research showed that the stimulus need not be so loud, and also that continued exposure may diminish the FI effects of masking (Garber & Martin, 1974). When compared with other stuttering reduction techniques (time-out, rhythmic stimulation, delayed auditory feedback), masking's effects may also be relatively less powerful and consistent (see Bothe, Davidow, Bramlett, & Ingham, 2006; Martin & Haroldson, 1979). It was selected for the present study, therefore, because it could be predicted to provide an intermediate level of fluency with no deterioration in speech naturalness, as compared with some other FI conditions.

Chorus Reading

One of the most intriguing features of developmental stuttering is the immediacy with which stuttering ceases when a person who stutters and an accompanist read aloud identical material (see Ingham, 1984). This has come to be known as the *chorus reading effect*; it has now been demonstrated to occur with a recorded accompanist (Ingham & Packman, 1979) and even when a person who stutters merely observes an accompanist speaking silently (Kalinowski, Stuart, Rastatter, Snyder, & Dayalu, 2000; Taylor, Bothe, & Everett, 2003). There is some evidence that chorus reading is the most powerful and reliable of the FI procedures (Johnson & Rosen, 1937): It can result in speech that may not always be distinguished from that produced by a normally fluent speaker (Ingham & Packman, 1979) and may not be significantly different from normally fluent speech according to observer-judged speech naturalness ratings (Ingham, Ingham, Finn, & Fox, 2003). It was important to the present study because it is a condition that could be predicted to produce both fluent and relatively natural-sounding speech.

Whispering

Whispering may be defined as "non-vocal sound with no carrying power produced by the arrangement of the glottis during exhalation" (Nicolosi, Harryman, & Kresheck, 1996, p. 305), or speech characterized by the almost complete absence of phonation. Bloodstein (1950), in his survey of conditions that reduce stuttering, found that about 52% of persons who stutter who responded (n = 46) reported they had very little or no stuttering when whispering. Johnson and Rosen (1937) originally reported about an 84% reduction in words stuttered during whispered oral reading. This finding was essentially replicated in a more recent study by Rami, Kalinowski, Rastatter, Holbert, and Allen (2005), although there are also reports of lesser reductions (Bruce & Adams, 1978; Perkins, Rudas, Johnson, & Bell, 1976). Whispering has also been described as requiring an increase in the speaker's level of vocal effort (Monoson & Zemlin, 1984), as compared with normal speech, presumably because of the unusual circumstance of producing articulatory movements but without phonation. Whispering was selected for this study, therefore, because it reduces stuttering, but at the distinct expense of naturalness and with the possibility of increased physical effort.

Rhythm

Rhythmic stimulation is one of the best documented methods for temporarily reducing or removing stuttering (see Ingham, 1984). The *rhythm effect* on stuttering occurs when the speaker is instructed to speak so that one syllable, one word, or even each phrase accompanies an external stimulus or is simply timed to an internal rhythmic beat by the speaker. Reduced stuttering is reliably produced across a wide range of speech rates, and, unlike masking, the rhythm effect does not appear to be constrained by duration of exposure (see Ingham, 1984). However, there is ample evidence that the reductions in stuttering are usually accompanied by unnatural sounding speech (see Bloodstein, 1995). Increased physical effort associated with an attempt to produce speech with a particular rhythm might also be hypothesized—hence, the importance of rhythm as the fourth condition in the present study.

The Present Study

In summary, this study was designed to test whether four well-established FI conditions, each of which could be expected to produce a different combination of stuttering, naturalness, and physical effort, produced differential effects on self-judged speech effort for speakers who do and do not stutter. These data were of interest in themselves, as an investigation of FI conditions, and also of interest in light of attempts to develop meaningful, reliable, and validly interpretable measures of speech effort. Thus, the study was also designed to compare the effects of FI conditions on experimenter-judged stuttering, speech rate, and speech naturalness. Based on previous research and the characteristics of each FI condition, two specific hypotheses were generated: (a) that chorus reading would produce significantly greater improvements in speech fluency, speech naturalness, and self-rated speech effort in persons who stutter, as compared with the other three conditions, and (b) that all FI conditions would result in increased speech effort and relatively more unnatural sounding speech in normally fluent speakers, as compared with normal reading.

Method

Participants

Twelve adults with persistent stuttering (PS group; 20–67 years; 8 men) served as participants in the stuttering group. All were volunteers selected from a clinic waiting list or from the pretreatment data collection phase of another study. They viewed themselves, and they had been previously diagnosed using standard clinical criteria, as persons with persistent chronic developmental stuttering. Prior to participating in this study, each member of the PS group completed a 3-min oral reading and a 3-min monologue to assess frequency of stuttering and eligibility for inclusion. All displayed at least 3.0% syllables stuttered (%SS) on both speaking tasks.

Twelve normally fluent speakers, matched pairwise by age (20–65 years) and sex (8 men) with the members of the PS group, served as controls. Controls reported no history of stuttering and showed no stuttering throughout this study. All participants in both groups reported a negative history of reading and hearing problems, and all denied any motor, sensory, or cognitive deficits that could interfere with the sensation or the self-measurement of physical effort associated with speech production. All participants passed a hearing screening in both ears at 25 dB HL at 500, 1000, 2000, 4000, 6000, and 8000 Hz. This study was preapproved by the Institutional Review Board at the University of California, Santa Barbara, and at the University of Georgia, and participants completed approved informed consent procedures before any data were collected.

Apparatus

All data were gathered using two computers and with participants sitting in a quiet or sound-treated room either in the presence of one experimenter or monitored by the experimenter from an adjacent control room. In all cases, two computers were used to manage presentation of stimuli, data recording, and audiovisual recording of the sessions. The primary computer was used to obtain measures of speech performance. These included measures of phonation, which were collected by means of an accelerometer placed over the prominence of the thyroid cartilage and held in place with an elastic and Velcro collar attached around the participant's neck (for details, see Ingham, Kilgo et al., 2001). Phonation data were stored automatically to the primary computer by the Modifying Phonation Intervals (MPI) software (Ingham, Moglia, Kilgo, & Felino, 1997) and served primarily to establish experimental fidelity for the whispering condition, as described in greater detail below. Measures of the three observer-judged dependent variables (stuttering frequency, speech rate, and speech naturalness) for this study were also gathered using the primary computer, through Stuttering Measurement System (SMS) software (Ingham, Bakker, Ingham, Kilgo, & Moglia, 1999). A second computer was used to deliver the experimental stimuli necessary for the masking, chorus recording, and rhythmic stimulus conditions and to store audiovisual digital recordings of all sessions using Windows Movie Maker files generated through a Canon Z70 digital video camera. A shotgun microphone attached to the camera (approximately 24 in. from the participant's mouth) was focused on the participant's mouth to provide high-quality audio recordings.

Procedure

Overall design. Each participant completed four sequences of ABA-format (Kazdin, 1998) reading trials, one sequence for each of the four FI conditions. During the A phases, the participants read aloud with no accompanying or altered stimulus condition; during the B phases, the reading tasks were accompanied by one of the four experimental stimulus conditions (masking, chorus reading, whispering, or rhythmic stimulation). Each A phase or B phase included five 1-min speaking trials, with each trial followed by approximately 1 min of rest and data storage; thus, the ABA triad for each condition required a total of 15 min of speaking time. The entire experiment required approximately 3 hr, including all breaks and instructions, for each participant. The rhythmic stimulation triad occurred last in each session, to reduce the known possibility of carryover from this condition. The other three experimental triads were presented in random order across participants.

At the beginning of the experiment, each participant read initial instructions that described the general format of the study (see Appendix A). The experimenter then asked the participant to explain what was required. When both were satisfied that the participant understood the general format, specific instructions for the first ABA triad were introduced. When those instructions were understood, the first A-phase trial of the first condition was completed. At the end of this 1-min trial, and at the end of all subsequent trials throughout the experiment, the participant was prompted by the software to enter a rating of speech effort for that minute. Physical effort was rated on a 9-point scale, using only whole numbers, with responses ranging from 1 (*highly effortless speech*) to 9 (*highly effortful speech*). During all conditions except chorus reading, participants read aloud from their choice of three books (Kagan, 1998; Linnea, 1995; Ridley, 1999). All trials during the chorus reading triads used the same prepared text, from a fourth source, because of the need for a prerecorded accompanist.

Masking. During the B phase of the masking condition, the participant read accompanied by white noise presented bilaterally through fitted foam ear tips at a self-selected maximal tolerable loudness level. Postexperiment evaluations verified that intensity of the signal varied across participants from 93 to 100 dB SPL.

Chorus reading. At the beginning of the chorus reading condition, the participant completed multiple 5- to 10-s practice readings, attempting to read in chorus with audio recordings of an adult female accompanist at different recording speeds. A total of 14 different rates were available; they ranged from 70% to 130% of the recorded reader's original 249 syllables per minute rate. The participant selected a most comfortable chorus reading rate and volume level. The experimenter verified that participants were reading with the accompanist by verifying that the audio signal was being provided, that the participant read continuously throughout the trial, and that the participant stopped at the same point in the reading material that the recording was known to stop.

Whispering. During the B phase of the whispering condition, the participant orally read in a whisper during each 1-min trial. The absence of phonation was verified in two ways: (a) by a perceptual check from the experimenter that the reading sounded overwhelmingly whispered and (b) by checking the number of phonated intervals produced during each reading via the MPI system. Whispering was defined as a 90% reduction in 30–1,000 ms phonation intervals (PIs) when compared with the participant's data from the immediately preceding A condition (see Nicolosi et al., 1996).

Rhythm. During the B-phase trials of the rhythm triad, the participant read aloud while attempting to match one spoken syllable to each audible "beat" (a 0.3-s tone) of an accompanying rhythmic stimulus. As in the chorus reading condition, each participant was allowed to select a comfortable rate (from among 10 available rates: 90, 100, 110, 120, 130, 140, 150, 160, 170, or 180 bpm) and signal volume level during repeated brief practice trials. Verification that participants were producing rhythmic speech was obtained by having research assistants listen to all recordings from the rhythmic speech ABA triads and rate each 1-min trial on a scale with responses ranging from 1 (*definitely producing rhythmic speech correctly*) to 7 (*definitely not producing rhythmic speech*; Davidow, Bothe, Andreatta & Ye, in press).

Data Analysis

Two research assistants shared data collection responsibilities approximately equally. Both had completed the Stuttering Measurement and Assessment Training (SMAAT; Ingham, Cordes, Kilgo, & Moglia, 1998) program and had also completed the training program associated with the SMS software (Ingham et al., 1999). They used the SMS program to count syllables spoken and syllables stuttered, with stuttering judgments made in accordance with the consensus judgments that serve as the training exemplars in the SMAAT and SMS training programs. They also rated speech naturalness, using Martin et al.'s (1984) scale, with responses ranging from 1 (*highly natural sounding speech*) to 9 (*highly unnatural sounding speech*) and again in accordance with consensus standards incorporated into the SMS training program. The SMS software converts the judge's counts of syllables spoken and syllables stuttered into percentage of syllables stuttered (%SS) and syllables per minute. In addition, because the SMS program also records data in terms of time intervals that either do or do not contain a stuttering judgment, it is possible to derive a measure of speech rate during stutterfree intervals only (stutterfree syllables spoken per minute [SFSPM] were calculated for this study from 5-s intervals). SFSPM was used in preference to global SPM for data analyses because it more accurately captures the rate of speech without the influence of stuttering. Thus, the observer-judged dependent variables for this study included %SS, SFSPM, and speech naturalness. These data, and the self-ratings of speech effort, were analyzed using a repeated measures multifactor analysis of variance (Winer, Brown, & Michels, 1991), with protected post hoc comparisons, in order to elucidate the experimental effects.

Reliability

The recordings of 6 PS group and 6 control group participants (50% of the data) were selected at random after the completion of the study for rescoring by two additional judges trained on the SMS and SMAAT programs but unfamiliar with this study. Trials from each participant were presented to the reliability judges in a randomized order. They rescored the trial recordings from a computer monitor using concurrently the Windows Media Player and the SMS program. Reliability was assessed by visual comparison between the experimenter's and reliability judges' scores in order to establish the validity of the experimental effects achieved during the experiment.

Results

Experimental Fidelity

Fidelity was obtained for the masking and chorus reading conditions on the basis of the presentation of the auditory stimuli and the experimenter's online judgment that the conditions were performed correctly. The use of whispering by participants was verified by measuring the total number of phonation interval counts in the 30–1,000 ms range in the A and B phases of the whispering triad. For the PS group, the PI totals for A1, B, and A2 phases were 510, 57, and 512, and for the control group the totals were 652, 10, and 675, respectively. Hence, there was clear evidence that the B phase involved dramatically reduced phonation. For the rhythm condition, across all participants, mean ratings on the 7-point scale used to assess judges' perception of rhythmic speech were 6.67 for A1 (preexperimental baseline) trials, 1.76 for B-phase (rhythm) trials, and 6.77 for A2 (postrhythm return to normal speech) trials; that is, A-phase speech was perceived by the judges as not rhythmic, and B-phase speech was perceived by the judges as consistently rhythmic.

Within-Group Comparisons

PS group. The solid squares in the left column of Figure 1 (%SS data), the condition means in Table 1, and the associated post hoc comparisons in Appendix B all show that the four FI conditions produced significant reductions in stuttering for the participants who stuttered, ranging from a 22% reduction during masking to a 99.5% reduction during rhythm. The minimal changes in speech rate shown in Figure 1 and Table 1 were significant for masking, rhythm, and whispering (Appendix B),

Figure 1. Mean speech effort (EFF), speech naturalness (NA), and stutterfree syllables per minute (SFSPM) for the persistent stuttering (PS) group (left) and the control group (right), with percentage of syllables stuttered (%SS) for the PS group only, for the five 1-min oral reading trials in each phase (A1, B, A2), and for each of four fluency-inducing conditions. Note that on the NA and EFF ordinate axis: 1 = highly natural sounding speech (NA), and 1 = highly effortless speech (EFF). A1 = first A condition; A2 = second A condition.

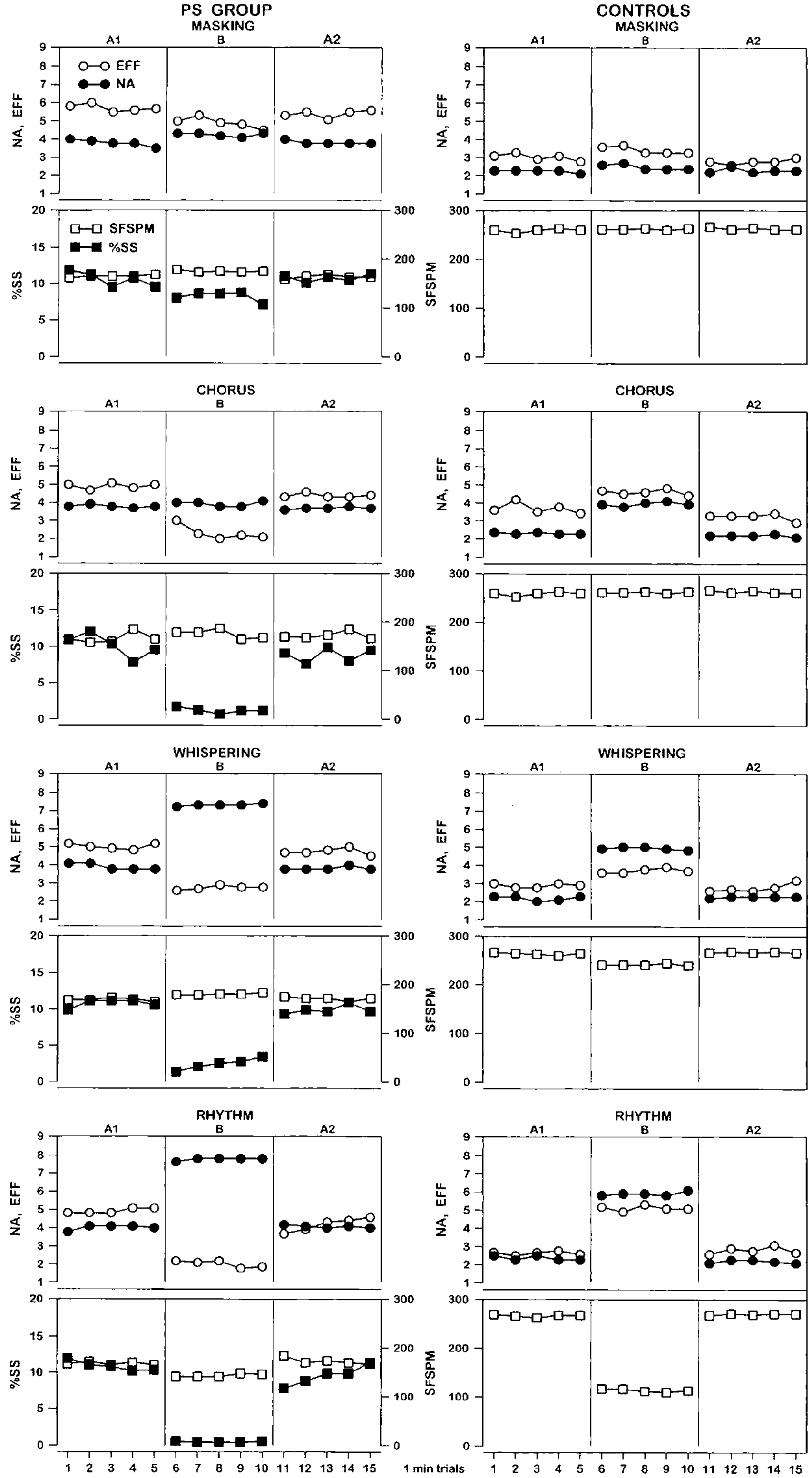


Table 1. Mean (with standard deviations in parentheses) speech effort (EFFORT), speech naturalness (NA), stutterfree syllables per minute (SFSPM), and percentage of syllables stuttered (%SS) for adults with persistent stuttering (PS) and controls (C) in normal speech (A1 and A2) and under four fluency-inducing conditions (B).

		Masking			Chorus			Whispering			Rhythm		
Variable	Group	A1	B	A2	A1	B	A2	A1	B	A2	A1	B	A2
EFFORT	PS	5.73	4.87	5.40	4.87	2.28	4.22	4.87	2.68	4.73	5.03	2.02	4.18
		(2.14)	(2.52)	(2.54)	(2.20)	(2.28)	(2.50)	(2.08)	(1.86)	(2.04)	(2.74)	(0.96)	(2.66)
	C	3.02	3.43	2.78	3.68	4.58	3.23	2.90	3.70	2.80	2.65	5.10	2.82
		(1.63)	(1.49)	(1.26)	(2.00)	(2.02)	(1.85)	(1.26)	(1.60)	(1.36)	(1.37)	(2.31)	(1.30)
NA	PS	3.78	4.22	3.83	3.82	3.95	3.67	3.93	7.27	3.85	4.02	7.75	3.97
		(1.55)	(1.48)	(1.38)	(1.25)	(0.82)	(1.17)	(1.27)	(0.79)	(1.18)	(1.29)	(0.78)	(1.04)
	C	2.23	2.50	2.27	2.33	3.89	2.19	2.18	4.92	2.27	2.38	5.91	2.18
		(0.48)	(0.56)	(0.54)	(0.74)	(0.92)	(0.50)	(0.48)	(1.82)	(0.62)	(0.64)	(2.28)	(0.46)
SFSPM	PS	163.6	174.2	163.0	167.8	174.7	171.4	168.5	179.9	171.0	168.0	144.2	173.1
		(40.8)	(52.0)	(51.1)	(41.2)	(20.2)	(39.8)	(43.7)	(37.9)	(46.7)	(50.6)	(47.8)	(48.6)
	C	258.8	262.2	264.0	260.6	209.7	263.4	264.5	241.8	267.7	267.4	114.6	271.5
		(27.3)	(29.1)	(31.4)	(25.9)	(26.8)	(23.4)	(29.7)	(32.3)	(32.8)	(28.3)	(21.0)	(31.6)
%SS	PS	10.61	8.27	10.78	10.20	1.26	8.94	10.76	2.45	9.87	11.40	0.52	10.13
		(11.18)	(9.79)	(13.21)	(10.22)	(1.70)	(11.56)	(10.38)	(4.64)	(10.66)	(13.97)	(1.00)	(12.79)
	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		—	—	—	—	—	—	—	—	—	—	—	—

Note. Em dashes indicate data not applicable.

but with Cohen's d scores of only 0.22 to 0.51. Speech naturalness showed significant deterioration in three of the four FI conditions; the exception was chorus reading, during which speech naturalness did not change significantly for this group. Self-rated speech effort, however, improved in all four conditions, with the changes ranging from approximately 1 scale point (0.7) in masking to almost 3 scale points in rhythm (2.6), and with d scores between 0.98 and 1.28 for chorus reading, whispering, and rhythm (Appendix B). Table 2 and Appendix C also show that the only significant difference between the first A condition (A1) and the second A condition (A2) in any triad for the PS group was for effort ratings before and after the B phase of the rhythm condition. This result is consistent with the known tendency for temporary carryover effects from rhythmic stimulation (Ingham, 1984).

Control group. Control group participants showed minimal but significant decreases in speech rate during chorus reading and whispering, and a substantial, significant decrease in speech rate during rhythmic speech, as compared with the relevant A-phase trials (right column in Figure 1, and Appendix B). The last of these results suggests that control participants all selected rates for the rhythmic condition that were significantly slower than their natural speech, a result that complicates interpretation of the naturalness and effort ratings for that condition (and that is also apparent in the PI data in Figure 1). Nevertheless, for the control group, speech naturalness was worse and speech effort was higher in all four B conditions, as compared with the A-phase ratings (Figure 1, Table 1, and Appendix B).

Between-Groups Comparisons

Comparisons across groups show that the participants who stuttered, as a group, spoke more slowly, less naturally, and with more self-reported effort than controls during baseline (A-phase) trials (Figure 1; see also Table 1). During the FI or B-phase trials, however, there was a consistent pattern of decreased effort by the PS group and increased effort by the control group. These patterns combined to result in the finding that the PS group reported speech to be less effortful during three of the four FI conditions (B phases) than control participants who reported under the same conditions. The exception was masking, in which the PS group's mean effort rating (4.90) exceeded the control group's (3.43).

Relationships Between Variables

Table 2 shows pairwise correlations between B-phase data for all FI conditions combined and for each of the four FI conditions. For the PS group, stuttering frequency and speech effort were moderately well correlated (r = .70 overall and .60–.78 in all FI conditions). The relationships between speech rate and effort varied somewhat by condition, but overall increased speech rate was not significantly associated with reduced effort (r = –.18 to –.39 for the PS group; –.05 to –.55 for the control group). Naturalness and effort were not significantly correlated

Table 2. Correlations between pairs of the four dependent variables (EFFORT, NA, SFSPM, %SS) for adults with persistent stuttering and the three dependent variables for the control group, shown for all experimental (B) phases combined and for each fluency-inducing condition separately.

Condition	Persistent stuttering				Controls		
			Conditions combined				
		NA	SFSPM	%SS		NA	SFSPM
	EFFORT	0.10	–0.32	0.70**	EFFORT	0.18	–0.33
	NA		–0.36	0.21	NA		–0.55*
	SFSPM			–0.58*			
			Each condition				
Masking		NA	SFSPM	%SS		NA	SFSPM
	EFFORT	0.65*	–0.39	0.60*	EFFORT	0.30	–0.05
	NA		–0.36	0.71**	NA		0.20
	SFSPM			–0.67*			
Chorus		NA	SFSPM	%SS		NA	SFSPM
	EFFORT	0.46	–0.34	0.71**	EFFORT	0.04	–0.21
	NA		–0.40	0.49	NA		–0.55*
	SFSPM			–0.64*			
Whispering		NA	SFSPM	%SS		NA	SFSPM
	EFFORT	–0.13	–0.57*	0.71**	EFFORT	0.24	–0.18
	NA		–0.15	0.01	NA		–0.28
	SFSPM			–0.66*			
Rhythm		NA	SFSPM	%SS		NA	SFSPM
	EFFORT	–0.08	–0.18	0.78**	EFFORT	0.24	–0.55*
	NA		–0.54	0.00	NA		–0.77**
	SFSPM			–0.44			

*$p < .05$. **$p < .01$.

for either the PS group ($r = .10$ for all data combined) or the control group ($r = .18$ for all data combined).[1]

Reliability

The replicability of the observer-generated data from this study, and of the conclusions drawn, was established through graphic comparison of the scores obtained by the experimenters and those obtained by the independent reliability judges. As shown in Figure 2, the two sets of %SS and SFSPM scores were in many cases virtually identical. In the case of the speech naturalness scores, there is more disparity between the experimenters' and independent judges' scores, but all relevant trends, similarities, and differences were identified by both judges.

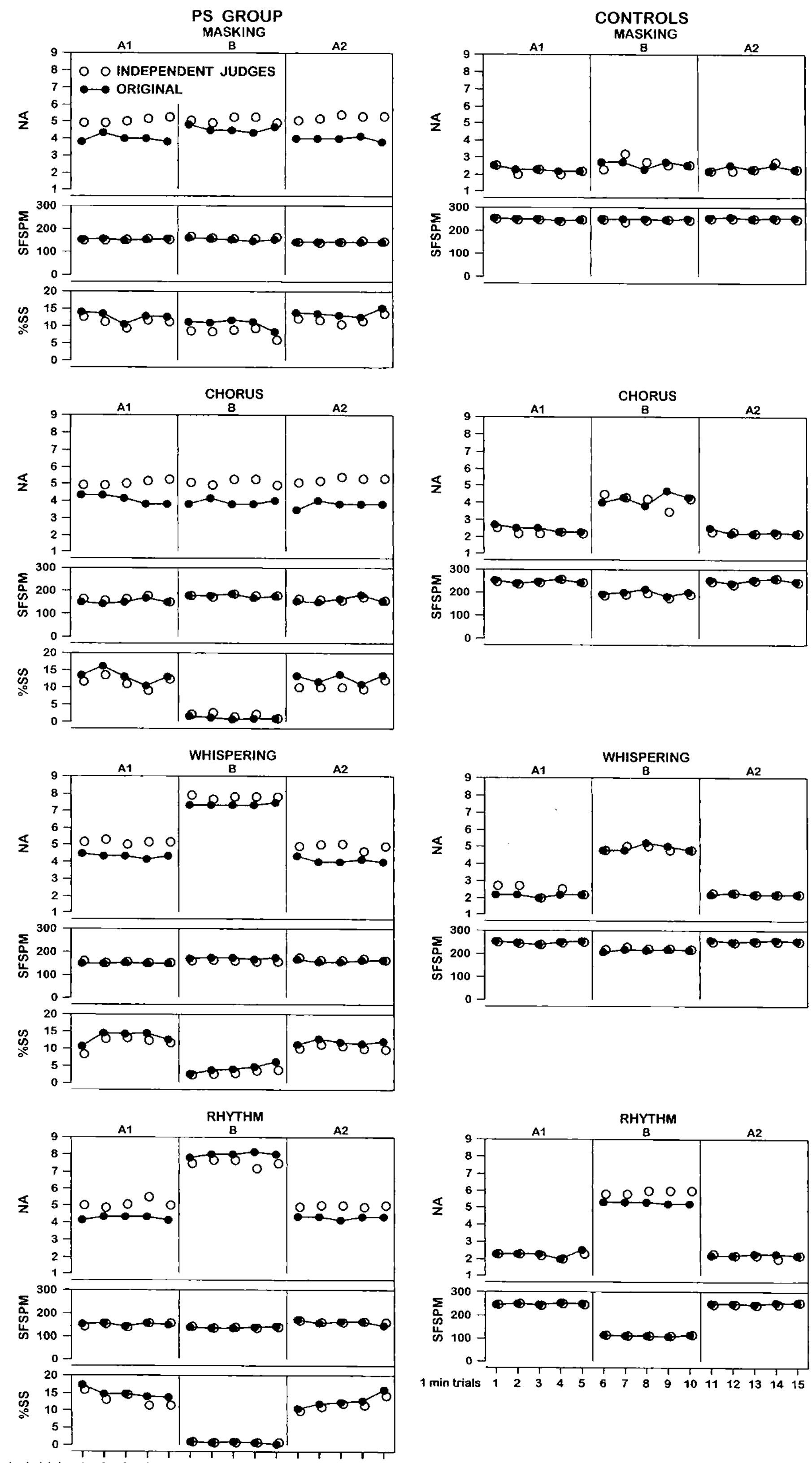
Discussion

The central findings of this study include the result that, for the PS group, all four of the FI conditions resulted in reduced stuttering and reduced speech effort. Masking, whispering, and rhythm, however, achieved these positive gains at the cost of a significant loss of speech naturalness. Chorus reading was the only FI condition that produced improvements in stuttering frequency and speech effort without some loss of speech naturalness. For the control group, all four FI conditions resulted in decreased naturalness, a result that is similar to that obtained for the PS group. In the controls, however, the FI conditions were associated with significantly increased effort, a change in the opposite direction from that shown by the PS group.

As mentioned in the introduction, a low or normal level of speech effort was described by Starkweather (1987) as one of four fundamental characteristics of normal fluency. As also discussed, previous investigations of this variable have been minimal, despite its status as the only self-judged variable mentioned by Starkweather and the widely acknowledged importance of self-judgments, as opposed to observer judgments, in stuttering treatment methods, goals, and outcomes (Franic & Bothe, 2008; Ingham & Cordes, 1997; Manning, 1999). The results of this study are encouraging and suggest further development and use of self-rated effort measures, although there are several complexities yet to be resolved.

[1]Given the wide age range of the participants (20–67 years), there is a possibility that part of the variance in speech effort rating changes might also be attributable to an age factor because the demands on speech physiology do change with age (Hixon, Weismer, & Hoit, 2008). However, Pearson product–moment correlations between participant age and mean changes in speech effort ratings across the experimental triads were not significant (PS, $r = .13$; controls, $r = –.17$).

Figure 2. Experimenters' and independent judges' mean scores for 6 participants in each group (persistent stuttering [PS] and control). Variables and conditions are as in Figure 1.



Complications, Interpretations, and Implications

Establishing normative levels of speech effort. The control group's mean for speech effort during all A phases in the present study was 2.98 (SD = 0.33) on the 9-point scale, with a range from 2.65 to 3.68 across the separate A phases. These ratings were more than a full scale point higher than the mean of 1.59 reported for controls in the Ingham et al. (2006) study upon which the present investigation was based. It remains unclear, therefore, what a normal level of speech effort might be, although it is also important to note that the oral reading rate of the control group was relatively fast in this study, averaging 264.7 SPM across all A-phase trials. This is considerably faster than the rate produced, on average, by normally fluent English speakers (see Kent, 1994). It is also faster than the controls' rate in the Ingham et al. study; although reading from the same materials, and rated in the same manner by judges who had completed the same training, their mean SPM rate was 186.3. It may be that the much faster oral reading rate adopted by the control speakers in the present study contributed to their perception of greater speech effort, as compared with the controls in the earlier study. Investigations of self-rated speech effort during a range of speech rates in adults who do and do not stutter could address this question and help to establish a normative value for effort ratings in normal, baseline, or A-phase speaking conditions.

Consistency and variability of effort ratings. Part of assessing any measurement system is establishing the reliability of obtained data. In the case of speech effort, factors such as vocal fatigue and the complexity of the reading material might be expected to change effort ratings over time, but effort ratings will only be meaningful if the variance across trials is relatively small in the short term and for similar topics or reading material. As was evident from the repeated A-phase data in Figure 1, it does appear that effort ratings are relatively stable in similar conditions. Correlations between effort ratings from A1 phases and those from A2 phases ranged from .90 to .92 for the PS group and from .90 to .96 for the control group. During B phases there was much more variability in performance, but during the last two of the five 1-min oral readings in each B phase, when performance was more likely to have stabilized, 90.0% of the PS group's speech effort ratings, and 91.2% of the control group's effort ratings, differed by 1 scale point or less. These results again provide initial evidence that effort ratings may be generally reliable and stable. The tendency for speakers who do not stutter to reduce their effort ratings after a period of speaking under a novel condition (i.e., the significant differences between A1 and A2 for the control group, Appendix C), however, deserves further investigation before the stability of effort ratings can be assumed.

Validity and interpretation of effort ratings. A third critical issue in the development of any new measurement is the extent to which it can be validly interpreted as a measure of the construct it was intended to measure. The absence of an overall correlation between effort ratings and speech naturalness (r = .10, top of Table 2) is therefore critical, suggesting as it does that speech effort ratings may help to quantify a construct that is independent from the general quality or naturalness of the resulting speech as perceived by listeners. At the same time, correlations between effort ratings and stuttering frequency were moderate (r = .60 to .78, bottom of Table 2). This finding suggests that self-ratings of the effort necessary to produce speech may be related to stuttering frequency, in a manner that validates an assumption of a relationship between effort and stuttering, while at the same time differing enough so that the two measures could provide nonoverlapping information. There is also the possibility that speakers were not differentiating between cognitive effort and physical effort or were not differentiating between the two consistently across conditions. It may also be that these two variables interact differently with each other, and with speech fluency and naturalness, for persons who stutter as compared with persons who do not. Future research could clarify these issues by arranging for participants to rate separately their cognitive effort and physical effort during multiple experimental conditions.

The present results are also consistent with many widely held but poorly studied beliefs about stuttering, including, especially, the notion that observers do not have access to the defining features of the disorder as experienced by persons who stutter (Perkins, 1985). Current attempts to address these notions have led to investigations of health-related quality of life (HRQL) in stuttering, which is by definition self-rated (Bramlett, Bothe, & Franic, 2006; Franic & Bothe, 2008; MacKeigan & Pathak, 1992). One standard description of HRQL defines it in terms of self-perceived physical, social, and role functioning and mental health (Bergner, 1985; McHorney & Tarlov, 1995), and the present results suggest the possibility that self-rated speech effort might be an important element of self-rated physical functioning in stuttering. Future studies of multiple self-rated physical variables, evaluated in the context of observer judgments and during stuttering as well as during FI conditions or treatment, could further the development of scales for the measurement of speech effort or other components of self-rated physical functioning or complete HRQL.

Clinical implications. Finally, any consideration of the clinical value of speech effort ratings assumes that there is not only a normative level of speech effort but also a desirable level that speakers would seek as a component of speech that they find fluent, normal, or acceptable

(Baer, 1988; Ingham & Cordes, 1997). However, that presumption may involve a number of complex issues. It seems likely, for example, that a desirable or satisfactory level of speech effort may vary across settings (e.g., during a relaxed conversation with a friend vs. during a contentious telephone conversation at work). It has been reported that levels of speech effort are functionally related to vocal frequency, intensity, and subglottic pressure during phonation (Colton & Brown, 1972; Prosek & Montgomery, 1969; Wright & Colton, 1972), features likely to vary with demands of speaking situations (Hixon et al., 2008). The present study shows that self-perceived effort also varied in ways that might have been predicted on the basis of the speaking situation. Normative values might emerge from studies such as that by Brown, Morris, and Murry (1996). They determined variability values for speaking fundamental frequency (SFF) and vocal intensity for repeated vowel, oral reading, and spontaneous speech utterances repeated three times a day over a 3-day period. Approximately

> +/–1 semitone of variability for SFF and approximately 2 db sound pressure level (SPL) variation in vocal intensity from any one experimental session to the next could be expected; individual variations within any group may reach two semitones and 6 db SPL. (Brown et al., 1996, p. 299)

Future studies of effort ratings might usefully combine physical measures, such as those used by Brown et al., with self-ratings; it may be, for example, that modulating vocal intensity could result in a comfortable level of effort along with fluency. At the same time, it may be that speakers can report experiencing satisfactory or acceptable levels of speech effort under a wide range of physical parameters.

Another approach for extending research in this area might parallel the approach taken previously with observer-judged and self-judged speech naturalness. If the goal is to reduce the physical effort associated with speaking, to reduce the client's concern or complaint about the physical effort associated with speaking, or both, then speech parameters that functionally control stuttering and that may also interact with perceived speech effort can be investigated. One possibility, for instance, might be reducing speech rate. This change often reduces stuttering in itself (Johnson & Rosen, 1937; Ingham, Martin, & Kuhl, 1974), and it also appeared in the present data to be associated with reduced speech effort. Other physical changes could also be investigated, including FI strategies that reduce the frequency of short PIs (Davidow et al., in press), treatment strategies that are described as using "easy" or "gentle" articulation or phonation, or even procedures that simply require the direct manipulation of phonatory behavior given biofeedback (Ingham, Kilgo et al., 2001). If such changes do reduce self-perceived effort, then they introduce the intriguing possibility that feedback about speech effort might be functional in reducing stuttering, just as speech naturalness ratings were first used as descriptors, or dependent variables (Martin et al., 1984; Schiavetti & Metz, 1997), and were then converted into a functional variable that can be fed back to the speaker with a resulting improvement in speech quality (Ingham & Onslow, 1985; Ingham, Sato, Finn, & Belknap, 2001).

Overall, the search for ways to exert functional control over the abnormal levels of self-rated physical effort reported by persons who stutter is an exciting challenge. More important, it has the potential to make important contributions to ongoing efforts to obtain complete and accurate measures of observer-judged and self-rated aspects of stuttering and of fluency, objectives that must be achieved as a prerequisite to the best possible management and treatment of stuttering.

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Appendix A. Instructions to participants.

General Instructions

This study is designed to measure the amount of physical effort that you use to speak. We will ask you to rate the amount of physical effort on a 9-point scale where 1 = highly effortless speech and 9 = highly effortful speech. We will ask you to make that rating after completing 1-min reading aloud tasks. These reading tasks will be organized so that you will read 5 without any accompanying condition occurring, 5 with one of four different accompanying conditions, and then 5 more without any accompanying condition. The accompanying conditions are often described as "fluency inducing" procedures because many who stutter find that they help them speak with much less or no stuttering. For descriptive purposes, we describe the preceding format as an ABA triad.

Instructions for Masking

In this study, we will assess the effect of having you listen in both ears to what is known as "white noise." This can be uncomfortable, but we want you to adjust the white noise volume to a level where you are almost unable to hear yourself reading aloud. You will always hear some of your speech because it is transmitted back to you through bone or muscle tissue, but most of your speech is air conducted and that is what we want to stop you from hearing. And so for this study we want you to adjust the noise level in your ears so that most of your speech cannot be heard.

Now we want you to practice briefly reading aloud with noise. We'll change the volume until you find a reasonably comfortable level that allows you to read aloud without hearing your voice. As soon as you hear the noise, please start reading aloud until the noise stops. Do you have any questions?

Instructions for Chorus Reading

The research assistant will play recordings of a person reading the passage in front of you at different speeds. We want you to practice briefly reading the passage in front of you to the accompaniment of the recording until you find the speed that best fits your natural reading rate. As soon as you hear the recording, we want you to try to read the same words AND then tell us if you want the volume adjusted. We will increase or decrease the volume until you find a level that allows you to hear the recorded words as you read them aloud and that you find the level to be comfortable.

Now we want you to select one of the recording speeds that you feel most comfortable in reading along with. Take your time and feel free to ask us to replay different recording rates until you find one that is most suitable for you.

When the experimental trials begin, don't worry if you fall behind the accompanist. Just move on in the text and try to keep up. Do the best you can. Do you have any questions?

Instructions for Whispering

In this part of the study, we want you to try to read aloud, but in a whisper or without moving your vocal cords. Try to do that now so that we can make sure you understand what's required.

Some people find this task difficult to do for very long because their throat gets dry fast. Have a sip of water between each 1 minute trial if you need to. When the whispering trials begin, don't worry if you briefly slip out of whispering. Just stop, and we will restart the trial. Do you have any questions?

Instructions for Rhythmic Reading

During this experimental phase, we want you to try to read aloud while you hear a rhythmic stimulus—a beep—through your earpiece insert. Actually, we want you to read so that each word or syllable accompanies each rhythmic beat. I will now demonstrate what your speech might sound like (research assistant demonstrates).

The research assistant will play for you 10 different rhythmic beeps, and we want you to try to read aloud with each of them. Try to read so that you accompany each word or syllable to each beat. To begin with, we want you to try to do this while hearing short amounts of 90, 100, 110, 120, 130, 140, 150, 160, 170, and 180 beats per minute. We will now give you a short amount of practice with each of these rates. Please ask to have the sound volume of the beat increased or decreased at any time until it is at a level that is sufficient for you to be able to read aloud while hearing the beat.

Now we want you to select one of the 10 beat rates that you feel most comfortable in reading along with. Take your time and feel free to ask the research assistant to replay different beat rates until you find which of the 10 is most suitable for you.

When the rhythmic speaking trials begin, don't worry if you fall behind the beat. Just try to keep up. Do the best you can. Do you have any questions?

Appendix B. Comparisons between all A-phase data (A1 and A2 combined, baseline plus postexperimental phases) and the relevant B-phase data (from fluency-inducing conditions) from 38 mixed-model analyses using noncentral *t* distributions in computing confidence intervals.

		Persistent stuttering group				Control group			
Condition	Variable	Difference between means	95% confidence interval of the difference		Cohen's *d*	Difference between means	95% confidence interval of the difference		Cohen's *d*
Masking	Effort	0.70[a]	0.39	1.01	0.29	−0.53[a]	−0.75	−0.31	0.36
	NA	−0.41[a]	−0.58	−0.24	0.28	−0.25[a]	−0.39	−0.11	0.54
	SFSPM	−10.93[a]	−16.61	−5.24	0.22	−0.80	−4.72	3.13	—
	%SS	2.43[a]	1.53	3.41	0.22	—	—	—	
Chorus	Effort	2.26[a]	1.77	2.74	0.98	−1.13[a]	−1.40	−0.84	0.57
	NA	−0.21	−0.50	0.08	—	−1.63[a]	−1.79	−1.46	2.08
	SFSPM	−5.14	−12.13	1.85	—	52.23[a]	46.57	57.90	2.03
	%SS	8.31[a]	6.49	10.13	1.07	—	—	—	
Whispering	Effort	2.12[a]	1.75	2.49	1.08	−0.85[a]	−1.18	−0.52	0.58
	NA	−3.38[a]	−3.59	−3.16	3.28	−2.70[a]	−2.97	−2.42	2.01
	SFSPM	−10.13[a]	−15.37	−4.88	0.24	24.23[a]	18.99	29.47	0.76
	%SS	7.87[a]	6.54	9.19	0.97	—	—	—	
Rhythm	Effort	2.59[a]	2.18	3.01	1.28	−2.37[a]	−2.73	−2.00	1.26
	NA	−3.71[a]	−3.97	−3.45	3.74	−3.63[a]	−3.98	−3.27	2.19
	SFSPM	24.89[a]	16.33	33.45	0.51	154.86[a]	148.88	160.82	5.99
	%SS	10.24[a]	8.15	12.33	1.08	—	—	—	

[a]Mean of data from A1 and A2 phases combined differed significantly from mean of B-phase data.

Appendix C. Comparisons between A1 (baseline) and A2 (postexperimental) data from 38 mixed-model analyses using noncentral *t* distributions in computing confidence intervals.

		Persistent stuttering group				Control group			
Condition	**Variable**	**Difference between means**	**95% confidence interval of the difference**		**Cohen's *d***	**Difference between means**	**95% confidence interval of the difference**		**Cohen's *d***
Masking	Effort	0.33	−0.02	0.69	—	0.23	−0.02	0.49	—
	NA	−0.05	−0.25	0.15	—	−0.04	−0.20	0.12	—
	SFSPM	0.60	−6.05	7.08	—	−5.20[a]	−9.73	0.67	0.25
	%SS	−0.17	−1.26	0.91	—	—	—	—	
Chorus	Effort	0.65	−0.23	0.88	—	0.45[a]	0.12	0.78	0.33
	NA	0.15	−0.26	0.41	—	0.14	−0.05	0.34	—
	SFSPM	3.60	−11.62	4.52	—	−2.77	−9.31	3.77	—
	%SS	1.26	−1.47	2.73	—	—	—	—	
Whispering	Effort	0.14	−0.29	0.56	—	0.10	−0.28	0.48	—
	NA	0.08	−0.33	0.17	—	−0.08	−0.40	0.24	—
	SFSPM	−2.50	−8.64	3.47	—	−3.22	−9.27	2.84	—
	%SS	0.89	−0.65	2.41	—	—	—	—	
Rhythm	Effort	0.85[a]	0.37	1.33	0.45	−0.17	−0.59	0.26	—
	NA	0.05	−0.35	0.25	—	0.20	−0.21	0.61	—
	SFSPM	−5.10	−14.00	5.77	—	−4.05	−10.94	2.84	—
	%SS	1.27	−1.13	3.69	—	—	—	—	

[a]Mean of A1 data differed significantly from mean of A2 data.