Effects of an Extended Version of the Lee Silverman Voice Treatment on Voice and Speech in Parkinson's Disease

Jennifer Spielman
National Center for Voice and Speech, Denver, CO

Lorraine O. Ramig
Leslie Mahler
University of Colorado at Boulder and National Center for Voice and Speech

Angela Halpern
National Center for Voice and Speech

William J. Gavin
Colorado State University, Fort Collins

Purpose: The present study examined vocal SPL, voice handicap, and speech characteristics in Parkinson's disease (PD) following an extended version of the Lee Silverman Voice Treatment (LSVT), to help determine whether current treatment dosages can be altered without compromising clinical outcomes.
Method: Twelve participants with idiopathic PD received the extended treatment version (LSVT-X), similar to LSVT except that it was administered twice a week in 1-hr sessions over 8 weeks and required substantially more home practice. Recordings were made in a sound-treated booth immediately before and after treatment, and again 6 months later. Vocal SPL was measured for 4 different tasks and compared with data from a previous study, in which participants with PD received traditional LSVT 4 times a week for 4 weeks. Listener ratings were conducted with audio samples from both studies, using sentence pairs from a standard passage. LSVT-X participants completed the Voice Handicap Index (VHI) before each set of recordings.
Results: Participants receiving LSVT-X significantly increased vocal SPL by 8 dB after treatment and maintained increased vocal SPL by 7.2 dB at 6 months. VHI scores improved for 25% of the LSVT-X participants following treatment, and listener ratings indicated audible improvement in speech.
Conclusions: LSVT-X successfully increased vocal SPL (which was consistent with improvements following traditional LSVT), decreased perceived voice handicap, and improved functional speech in individuals with PD. Further large-scale research is required to truly establish LSVT-X efficacy.

Key Words: Parkinson's disease, clinical research, voice treatment, dysarthria

Over the past 15 years, the Lee Silverman Voice Treatment (LSVT) has been established as the most efficacious behavioral treatment for voice and speech disorders in Parkinson's disease (PD; Pinto et al., 2004; Ramig, Countryman, Thompson, & Horii, 1995; Ramig, Sapir, Countryman, et al., 2001; Ramig, Sapir, Fox, & Countryman, 2001; Schulz, 2002; Yorkston, Spencer, & Duffy, 2003). To date, the LSVT is the only speech treatment for PD supported by published Level I efficacy data (C. Goetz, personal communication, March 2003; Ramig, Sapir, Countryman, et al., 2001), and LSVT research currently comprises the majority of peer-reviewed publications in the area of phonatory-respiratory treatment for dysarthria (Yorkston et al., 2003). The LSVT has also been applied successfully to treat voice and speech

disorders in adults with multiple sclerosis (Sapir et al., 2001) and ataxic dysarthria (Sapir et al., 2003), and in children with cerebral palsy (Fox, Boliek, & Ramig, 2005) and Down syndrome (Robinson, Petska, Halpern, Ramig, & Fox, 2004).

All published LSVT outcome data to date are based on a treatment schedule of four individual treatment sessions of 50–60-min duration per week for 4 consecutive weeks. These data document both short- and long-term effects on voice and speech (Ramig, Sapir, Countryman, et al., 2001; Ramig, Sapir, Fox, & Countryman, 2001), and also reveal the potential impact of LSVT on facial expression, swallowing, and neural function (El-Sharkawi et al., 2002; Liotti et al., 2003; Narayana et al., 2005; Spielman, Borod, & Ramig, 2003). These consistent and well-documented outcomes are particularly significant in light of early opinions that all but dismissed the effectiveness of speech treatment for PD (Allan, 1970; Sarno, 1968). Such convictions were later called into question by studies that employed more frequent and intensive treatment (Johnson & Pring, 1990; Robertson & Thomson, 1984) and started reporting successful outcomes. It is now believed that intensity of treatment (hour-long, high-effort sessions), frequency of clinical contact (four times a week for 1 month), sensory retraining (Fox, Morrison, Ramig, & Sapir, 2002), and simple instructions ("think loud") are key to the success of the LSVT. The classic speech and voice improvements seemed to require more frequent and intensive practice in order to make the transition from an externally cued (performance) response to a spontaneous, internally generated (learned) behavior.

Another long-held belief likely to have influenced early treatment approaches is that the speech and voice characteristics associated with PD, including reduced loudness, monopitch and monoloudness, and imprecise articulation (Darley, Aronson, & Brown, 1969a, 1969b), resulted entirely from underlying rigidity and decreased muscle activation. PD certainly is accompanied by measurable changes in laryngeal muscle activation (Baker, Ramig, Luschei, & Smith, 1998; Luschei, Ramig, Baker, & Smith, 1999) associated with significantly decreased vocal SPL (Fox & Ramig, 1997). However, recent research on motor learning with people who have PD has revealed additional motor and cognitive changes that help explain why overcoming these deficits has been particularly challenging. For example, the discrepancy between the ability to perform well in response to an external cue and the apparent inability to internally cue oneself is a fundamental aspect of bradykinesia, one of the key signs of PD (Berardelli, Rothwell, Thompson, & Hallett, 2001). The muscle activation deficits that occur in bradykinesia are believed to result from inadequate merging of kinesthetic feedback, motor output, and context feedback within the basal ganglia that is necessary to select and reinforce an appropriate gain in the motor command (Berardelli et al., 2001; Desmurget, Grafton, Vindras, Grea, & Turner, 2004). This is supported by single-cell recording studies (Turner & Anderson, 1997) and recent brain activation imaging studies (Desmurget et al., 2004; Turner, Grafton, McIntosh, DeLong, & Hoffman, 2003; Turner, Grafton, Votaw, DeLong, & Hoffman, 1998) showing a correlation in activation of neurons or muscle with increasing movement amplitude.

With regard to speech, abnormal sensory processing of the reduced amplitude output may contribute to the commonly reported feeling that the speaker is using sufficient effort for loud and intelligible speech, when in fact vocal SPL and articulatory precision are reduced. The perception is so strong that people with PD routinely insist that their friends and spouses are losing their hearing rather than consider that they may be speaking softly (Fox et al., 2002). We hypothesize that training amplitude targets the proposed pathophysiological mechanisms underlying bradykinesia—inadequate muscle activation (Farley, Sherman, & Koshland, 2004; Hallett & Khoshbin, 1980; Pfann, Buchman, Comella, & Corcos, 2001). This is done via intensive sensorimotor training that teaches clients to recognize and use increased effort and louder speech during everyday living. In this manner, we do not try to bypass basal ganglia pathology but instead attempt to improve basal ganglia functioning, as well as utilize other possible compensatory brain mechanisms. By directly addressing this sensory mismatch, LSVT teaches clients with PD to recalibrate their perception of normal loudness so that by the end of 1 month of therapy, they spontaneously speak with greater amplitude; that is, the internal cue for amplitude is restored or improved.

Behavioral treatment of voice and speech in PD therefore involves learning to speak at a level of loudness that the client perceives to be too loud and that requires more than usual effort. This loudness level is perceived by listeners to be within normal limits. Additionally, as the automaticity of speaking and scaling vocal loudness is disrupted by damage to the basal ganglia in PD, the speaker must do purposefully what had once been done automatically (Brown & Marsden, 1991; Darley, Aronson, & Brown, 1975). Because the output of speech production subsystems is scaled down, treatment requires clients with PD to learn new output parameters for existing motor programs in order to produce intelligible speech. Education regarding sensory awareness of the internal cue that represents the appropriate levels of effort and loudness is also required. Morris and Iansek (1996) recommended treatment strategies that incorporate cueing and repetition to elicit more normal movement in clients with PD. Overlearning a new motor task through intensive practice and repetition has the potential to improve task automaticity, decrease the perception of effort required to perform the task, and create a stronger memory (habit) for the motor behavior (Schmidt & Lee, 1999). Intensity of practice is also emerging as a key variable in neural plasticity and the recovery of function following brain damage (Fisher & Sullivan, 2001). By incorporating these principles of repetition, high intensity, and high frequency of practice, LSVT appears to help shift "loud" speech from a performance in response to an external cue to a learned, internally cued response.

In addition to increasing vocal loudness levels for daily communication, there is evidence that the frequent, intensive practice and repetition of LSVT generate other changes in speech production, including improvements in voice quality, speech intelligibility, and articulation (Baumgartner, Sapir, & Ramig, 2001; Dromey, Ramig, & Johnson, 1995; Spielman, Ramig, & Fox, 2005), and promote positive changes that extend to nonverbal behaviors, such as facial expression (Spielman et al., 2003) and swallowing (El-Sharkawi et al., 2002). These distributed effects of LSVT may be the result of reported evidence for neural coupling of orofacial muscles

to neural systems of laryngeal and respiratory control in human studies (McClean & Tasko, 2002). Neural coupling may explain, in part, the potential spread of effects from stimulation of increased vocal effort and loudness (respiratory and laryngeal systems) to orofacial muscles (articulation, oral phase swallowing). Recent neural imaging studies using positron-emission tomography demonstrate a shift of brain activity for speech following LSVT (Liotti et al., 2003; Narayana et al., 2005), whereby abnormal levels of cortical activation before treatment are reduced following treatment, and basal ganglia activation increases. Taken together, these changes are believed to reflect more normal and greater activation across motor systems, driven in part by increased amplitude of movement that is gained through training vocal loudness.

All speech-language pathologists certified in the LSVT are instructed to administer four individual treatment sessions per week for 4 weeks. In order to preserve the quality of treatment outcomes, the trademarked name "LSVT" is used only when the treatment is administered as prescribed. However, for speech-language pathologists in a variety of working situations, the frequency of treatment can become an obstacle to providing LSVT. Clients, especially those who have mobility trouble and/or are still employed, may also find this schedule challenging. As a consequence, rather than withhold treatment, clinicians may provide group therapy or simply offer fewer weekly sessions. Although such treatments may have merit, the few available studies examining the effects of modifying the administration of LSVT remain inconclusive (see Stroud & Belin, 2004; Wohlert, 2004), mostly due to methodological differences with existing LSVT efficacy literature.

Given the realities of scheduling and reimbursement in the clinical world, it is important to evaluate whether the LSVT can be implemented with more flexibility than has been previously reported. The current schedule of LSVT—16 sessions, each an hour long, delivered over 4 weeks—is thought to contribute to successful learning, consistent with theories suggesting that intensity and repetition of practice improve learning and performance (Kleim, Jones, & Schallert, 2003; Schmidt & Lee, 1999). However, extending practice over a longer period of time (e.g., two times a week for 8 weeks) may also help establish new behaviors and improve performance in PD because it allows for additional practice during the treatment period.

The purpose of the present study was to examine the effects of an extended version of the LSVT, henceforth "LSVT-X," defined by the same amount of clinician contact time (16 hr) extended over a longer period of time. We chose an administration of two 1-hr clinic sessions a week for 8 weeks, maintaining the schedule of daily home practice and carryover assignments from traditional LSVT. This schedule preserved the total number of clinic-based therapy sessions typically administered but distributed them over a longer time period. Providing treatment twice a week in 1-hr sessions maintained some of the potency of more frequent and intensive treatment but reduced the weekly face-to-face time commitment for both therapists and clients. This schedule also allowed for more at-home practice (homework) during the treatment period, which might be helpful in establishing new habits. A key element of this dosage was that homework exercises were not optional and were considered to be a significant part of the treatment plan. These clients were required to practice at home once (for 5 to 10 min) on days they received treatment in the clinic, and twice (for 20 to 30 min total) on days they did not receive treatment. Compliance with this homework requirement was closely monitored and strictly enforced.

To evaluate the effects of treatment, we measured vocal SPL, perceived voice handicap, and functional communication in PD, and compared outcomes with an earlier efficacy study in which similar individuals received traditional LSVT (Ramig, Sapir, Fox, & Countryman, 2001). Vocal SPL was chosen to reflect the most basic, objectively quantifiable treatment effect to be expected following traditional LSVT, correlating with vocal loudness. Functional improvement in communication was measured using both speakers' perceptions of their level of voice handicap (Voice Handicap Index [VHI]; Jacobson et al., 1997) as well as listener ratings of paired speech samples recorded before and after treatment. We asked the following questions:

1. Is there a significant change in vocal SPL after LSVT-X treatment?
2. Were any observed changes maintained at 6 months?
3. Does LSVT-X produce changes in vocal SPL comparable to increases observed in a previous LSVT study?
4. Is there evidence of functional improvement in communication following LSVT-X?

Method

Participants

Fifteen participants (10 men, 5 women) diagnosed with idiopathic PD were recruited from the Denver, CO, area to participate in LSVT-X treatment. All participants signed the human consent form approved for this study by the institutional review board of the University of Colorado, Boulder, and were provided therapy free of charge. Because the performance of these participants was intended to be compared with results from a past study, all 15 recruited participants were placed directly in the LSVT-X treatment group (henceforth X-PD). However, in order to make sure their level of motivation was consistent with past participants, during recruitment all individuals were told that they could be placed at random into either a 1-month group (receiving treatment four times a week for 4 weeks) or a 2-month group (receiving treatment twice a week for 8 weeks). All participants expressed willingness to join either group. At the end of the study, all participants were debriefed regarding the pretense that there were two treatment groups. One male participant was discharged midway through the therapy due to complications from an unrelated medical condition, and results from 2 female participants were later omitted after their diagnoses changed from idiopathic PD to Parkinson's Plus syndromes (one participant was diagnosed with multiple systems atrophy and the other with progressive supranuclear palsy).

The final group of 12 new participants (9 men and 3 women) was compared before and after treatment with two other groups of participants from an earlier study conducted by members of the same research team (Ramig, Sapir, Fox, & Countryman,

2001). In the earlier study, one group of participants with PD (henceforth T-PD; $n = 14$; 7 men and 7 women) received traditional LSVT, and another group of control participants with PD (henceforth NT-PD; $n = 15$; 7 men and 8 women) received no treatment. All participants were required to see an otolaryngologist before participating in the current study, in order to exclude anyone for whom high-effort voice therapy was not appropriate, as well as anyone who had laryngeal findings inconsistent with PD. Participants in both studies were stable on their antiparkinsonian medications throughout. Formal cognitive testing was not done; however, all participants were living independently and able to complete all evaluation and treatment tasks. All participants had speech and voice characteristics typical of PD, as evaluated by three speech-language pathologists with extensive experience working with this population.

A 2 × 3 (Gender × Group) analysis of variance (ANOVA) was used to examine possible differences among current and historical groups for age, years since diagnosis, stage of disease (Hoehn & Yahr, 1967), and severity of dysarthria (0–5, where 0 = *none* and 5 = *severe*), followed by post hoc Tukey *t* tests ($\alpha = .05$). No significant differences were found for any of the variables among any groups. Group characteristics appear in Table 1.

Treatment

Participants in the X-PD group received two 1-hr sessions of LSVT-type treatment per week for 8 consecutive weeks. Treatment followed the tasks and hierarchy of traditional LSVT (Ramig, Countryman, O'Brien, Hoehn, & Thompson, 1996; Ramig et al., 1995), except the hierarchy was distributed over 2 weeks for each type of task. In brief, LSVT uses multiple repetitions of high-effort, loud, sustained "ahs" (15 repetitions), high- and low-pitch glides (15 repetitions each of high and low pitch), and functional sentence repetition (5 repetitions of 10 sentences) to train healthfully produced, increased loudness. These daily tasks make up the first half of the treatment sessions. This louder voice is then carried over into speech using a hierarchy in which the utterances increase in length and complexity over the 4-week period. The speech hierarchy makes up the second half of the treatment session. As in the typical LSVT schedule, participants also completed 5 to 10 min of homework once a day on treatment days, and 20 to 30 min of homework on nontreatment days. Homework sheets with assigned tasks and carryover activities were provided at each session and completed by participants on a daily basis. Other than extending the treatments sessions over a longer period of time, the main difference between the two approaches is that LSVT-X requires a significantly greater amount of home practicing (96 assignments for LSVT-X versus 40 assignments for LSVT). The Appendix provides a comparison of the two treatment schedules. As noted above, home practice was not optional, and the clinician began each session with a check of all assigned homework and carryover activities.

Data Collection

Participants were recorded twice during the week before therapy (pre1 and pre2), twice immediately after therapy (post1 and post2), and twice at 6 months following therapy (follow-up1 and follow-up2). Acoustic data were collected in an IAC sound-treated booth. All equipment and conditions were the same as those used to collect data for the previously published study (Ramig, Sapir, Fox, & Countryman, 2001) that served as comparison data (see Statistical Analysis subsection below). No treating therapist collected data, and therapists were kept out of sight during data collection to avoid acting as external cues or biasing data collection. Participants were asked to sustain phonations, read standard paragraphs, describe a standard picture, and talk spontaneously as part of a larger protocol. As in past studies, participants were never cued for vocal loudness during data collection sessions. Tasks were repeated over 2 recording days to examine speech variability, which is often described in this population (King, Ramig, Lemke, & Horii, 1994). Participants were stable on their medications, and all attempts were made to keep recording times consistent across sessions and to collect data from participants at the same time in their medication cycles, typically 1 hr after taking medications.

Acoustic data were transduced using a head-mounted condenser microphone (AKG 410) positioned at a distance of 8 cm from the speaker's lips and recorded to a two-channel digital audiotape at a sampling rate of 22.5 kHz per channel. SPL data were collected directly with a high-quality Type 1 sound level meter (Bruel & Kjaer Model 2230) placed at a distance of 30 cm from the speaker's lips. SPL measurements were recorded by hand using the method established by Fox and Ramig (1997). In this method, the data collector hand records peak SPL information displayed in 1-s intervals throughout each speech task and constantly monitors the distance from mouth to sound level meter between tasks. This method yields mean SPL comparable to software-derived measurements (Ramig et al., 1995) and was chosen in order to duplicate the procedures used in the Ramig, Sapir, Fox, and Countryman (2001) study. To measure psychosocial functioning related to voice, participants completed the VHI (Jacobson et al., 1997) before and after treatment, and again at the 6-month follow-up visit. The VHI is a questionnaire with 30 statements (e.g., "My voice makes it difficult for people to hear me") reflecting physical, functional, and emotional aspects of voice production and potential handicap relating to specific voice difficulties.

Perceptual Ratings

Four speech-language pathology graduate students took part in a listening study designed to evaluate perceptible changes in connected speech following treatment, using a paired comparison paradigm. Listeners were presented with a pair of sentences extracted from a reading of "The Rainbow Passage" (Fairbanks, 1960) for each participant, recorded during pre1 and post1 data collection sessions. Sentence pairs were extracted at random from six possible sentences, and normalized for SPL using a custom-built MATLAB software program (Mathworks, 1999). Although therapy focused on increasing vocal loudness, we chose to examine other aspects of speech that would indicate improvement in speech and voice production, because we already had objective measures of SPL. Specifically, raters were asked to base their judgments

TABLE 1. Mean age, time since diagnosis, stage of disease (Hoehn & Yahr, 1967), voice and speech severity, and voice and speech characteristics for participants in each of three groups.

Group	Participant	Age (years)	Years since diagnosis	Hoehn & Yahr stage	Voice and speech severity	Voice and speech characteristics
X-PD	1	62	11	2	1	Reduced loudness, breathy
	2	45	4	—	1	Reduced loudness, monopitch
	3	60	5	2	0	
	5	61	5	3	2	Imprecise articulation
	6	82	6	2	5	Hoarse, breathy, monopitch, imprecise articulation
	7	80	0.5	—	4	Breathy, monopitch and loudness
	8	75	7	3	3	Hoarse, reduced loudness, imprecise articulation
	9	70	8.5	3	4	Strained/strangled, fast rate, reduced loudness
	11	71	3	3	3	Reduced loudness, monopitch, breathy
	13	69	4	2.5	1	Breathy, reduced loudness
	14	69	1	2	5	Imprecise articulation, variable rate, breathy, reduced loudness
	15	62	2	2	2	Breathy, reduced loudness, pressed voice
M		67.2	4.8	2.5	2.6	
SD		10	3.1	0.5	1.7	
T-PD	1	67	17	5	4	Fast rate with palilalia, breathy, hoarse, imprecise consonants
	7	59	8	—	2	Breathy, reduced loudness, monopitch and loudness
	8	59	2.5	—	3	Reduced loudness, slow rate, diplophonia, imprecise consonants
	10	60	4	—	5	Imprecise articulation, breathy, reduced loudness
	12	51	4	2	0	
	14	76	3	—	4	Strained/strangled with pitch breaks, imprecise consonants, breathy
	19	74	17	4	4	Strained/strangled, breathy, pitch breaks
	23	79	1.5	—	0	
	27	80	3	—	3	Hoarse/strained, imprecise articulation
	35	61	—	—	3	Reduced loudness, vocal fry, monopitch
	37	76	20	4	5	Reduced loudness, imprecise articulation, monopitch and loudness, breathy, tremor, slow rate
	38	67	7	2	2	Fast rate
	40	75	15	3	1	Hoarse
	42	66	8	2	4	Reduced loudness, monopitch, imprecise articulation
M		67.9	8.6	3.1	2.9	
SD		9	6.3	1.2	1.7	
NT-PD	9	74	2	2.5	1	Reduced loudness, breathy
	13	70	7	2	0	
	16	64	19	3	4	Reduced loudness, hoarse, monopitch
	18	64	6	3	3	Reduced loudness, monopitch breathy, imprecise articulation
	20	91	2	3	2	Mono pitch, reduced loudness
	21	77	6	2	1	Hoarse, reduced loudness
	24	47	0.5	1	0	
	25	80	7	2	3	Imprecise articulation, tremor, monopitch, strained, variable rate
	26	72	12	2	3	Strained, hoarse
	28	79	6	—	2	Reduced loudness, vocal fry, monopitch
	30	70	8	2	3	Hoarse/strained/pressed
	32	80	17	2.5	3	Hoarse/strained
	36	78	—	—	4	Reduced loudness, hoarse/strained, imprecise articulation, mono pitch
	39	48	1	1	4	Reduced loudness, hoarse/strained, fast rate
	43	74	8	3	2	Monopitch, breathy
M		71.2	7.4	2.2	2.3	
SD		11.8	5.4	0.7	1.3	

Note. Hoehn & Yahr stages range from 1 to 5, with higher stages indicating greater severity. Severity ratings of speech and voice deficits are on a scale of 0 to 5, with 0 = *none*, 1 = *mild*, 3 = *moderate*, and 5 = *severe*. Dashes indicate that data were not available. X-PD = Lee Silverman Voice Treatment–Extended (LSVT-X) Parkinson's disease (PD) treatment group; T-PD = treated PD group from Ramig, Sapir, Fox, & Countryman (2001); NT-PD = untreated PD group from Ramig, Sapir, Fox, & Countryman (2001).

on voice quality, articulatory clarity, rate, intonation, and naturalness.

Presentation was randomized by both participant and condition (pre- or posttreatment), such that pre- and posttreatment conditions were paired for each speaker but their order within each pair was randomized. Samples were presented via computer, and listeners decided whether the second sample sounded better than the first (a rating between 1 and 50), the same as the first (a rating of 0), or worse than the first (–50 to –1) using a visual analog scale from –50 (*much worse*) to +50 (*much better*). Each new sentence pair was presented on a screen with the scale and the instructions clearly visible. Twenty percent of the pairs were repeated to measure intrarater reliability.

Statistical Analysis

Performance of the X-PD group on each of the four speech and voice tasks for this study (sustained phonation, reading "The Rainbow Passage," monologue, and picture description) was evaluated using a 2 × 3 × 4 completely randomized block ANOVA design that examined differences between data collected at each time period (i.e., between pre1 and pre2, between post1 and post2, and between follow-up1 and follow-up2 recordings). There were no significant differences between the recording days at each time before and after treatment and at follow-up, though an overall trend toward increasing intensity from the follow-up1 to the follow-up2 recording was observed. Therefore, to simplify the ANOVA design and increase its power, the data for each participant at each time period were averaged to produce mean pretreatment, posttreatment, and follow-up scores. These data were then reevaluated using a 3 × 4 completely randomized block ANOVA design. The first factor was the three levels of the assessment time (pretreatment, posttreatment, and follow-up). The second factor was the four levels of the assessment conditions (phonation, Rainbow, picture, and conversation). Post hoc comparisons using Tukey tests were applied to determine which means significantly differed from each other.

The interpretation and generalization of the outcomes of the above analyses are restricted because this study of LSVT-X does not have a control group that received either no treatment or an alternative treatment as in previously published studies on LSVT. To address the issues of generalization, it would be desirable to know whether the treatment effect observed in the participants receiving LSVT-X compares favorably to the control groups or groups receiving typical LSVT (Ramig, Sapir, Fox, & Countryman, 2001). However, given that the earlier published data were collected under different experimental protocols in a different laboratory (albeit similar to the current study), direct comparisons of group performances by incorporating data from both studies into a single ANOVA procedure may violate assumptions concerning equality of variance, because the studies may have different sources and degrees of measurement error. An alternative approach is available if one assumes that a reasonable estimate of the mean vocal SPL of two different "populations" can be made from the previously published data. The newly obtained data under the LSVT-X protocol would be represented as a sample mean to be statistically compared with each of the estimates of the population means (published data) using a variation of *z* test of means; in this case, a one-sample *t* test where the population variance needed for the error term is estimated from the sample variance (Sheskin, 1997). In keeping with standard practice of controlling for Type I errors by multiple testing, the alpha level of a given *t* test is adjusted by dividing the family-wise error rate of .05 by the number of tests performed, in this case 24. Thus, the adjusted alpha level is .0021 for the analyses that are reported in Tables 3 and 4 (see discussion below).

The ANOVA and the one-sample *t* tests test were performed using SPSS Version 12, and the post hoc *t* tests were calculated by hand according to the formulas described in Kirk (1995).

Results

Questions 1 and 2: Is There a Significant Change in Vocal SPL After LSVT-X Treatment? Were Any Observed Changes Maintained at 6 Months?

The 3 × 4 randomized block ANOVA revealed that in all conditions, substantial increases in SPL were seen from pre- to posttreatment, with slight decreases from posttreatment to follow-up (see Figure 1 and Table 2). ANOVAs revealed a significant main effect for time of assessment, $F(2, 20) = 89.61$, $p < .001$, with a large effect size ($\eta^2 = .90$). Post hoc tests revealed a significant increase from pre- to posttreatment ($t = 8.80$, $p < .001$), a significant increase from pretreatment to follow-up ($t = 7.42$, $p < .001$), and a nonsignificant decrease between posttreatment and follow-up.

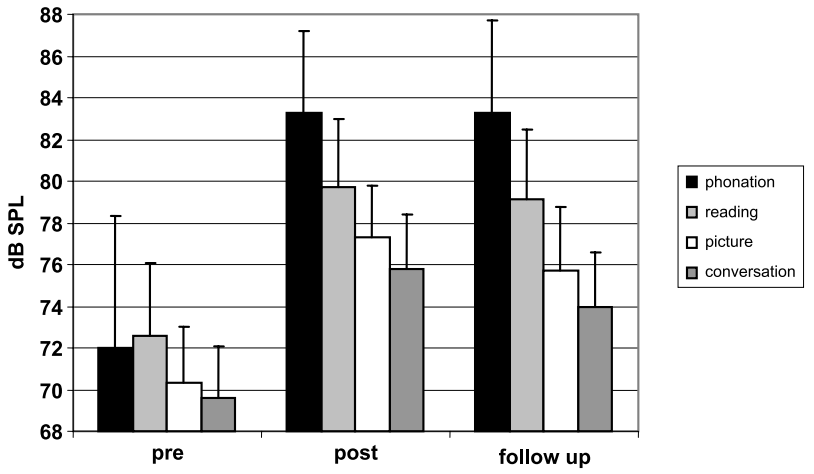
There was also a significant interaction effect for Time of Assessment × Test Condition, $F(2, 20) = 15.15$, $p < .001$, with a moderate effect size ($\eta^2 = .60$). Post hoc testing indicated that all speaking conditions showed significant increases in SPL from pre- to posttreatment and from pretreatment to follow-up, with the exception of conversation at follow-up. There was no significant decrease in SPL from posttreatment to follow-up for any condition.

Question 3: Does LSVT-X Produce Changes in Vocal SPL Comparable to Increases Observed in Previous LSVT Studies?

Estimation of population means before treatment. Using the data published in Ramig, Sapir, Fox, and Countryman (2001), the population means for SPL were estimated to be represented by the group means reported for each speech condition (see Table 3). In general, the means of the X-PD group before treatment were slightly higher than means representing estimates of the performance of the population derived from both the treated and untreated groups in the Ramig et al. study. Single-sample *t* tests revealed that none of these differences were statistically significant. Thus, the comparisons at all four conditions met the expectation that the newly collected X-PD means were representative of SPL data for individuals with PD previously reported.

Group means following treatment. Table 4 presents SPL means for all groups and all four tasks, before and after treatment. No statistically significant differences between the population means derived from the T-PD group in the 2001 publication and the X-PD sample were found in three of the

FIGURE 1. Measurement of SPL at 30 cm in the Lee Silverman Voice Treatment–Extended group for four different speech tasks before, immediately after, and 6 months after therapy.



four conditions. For the picture condition, the difference between the population mean derived from the T-PD group and the X-PD sample mean was found to be statistically significant, the X-PD group mean being larger. At 6 months, no statistically significant differences between these groups were found in any of the four conditions.

As expected, statistically significant differences between the population mean derived from the NT-PD group (control) in the 2001 publication and the X-PD sample were found in all four conditions after treatment and at follow-up, the X-PD group having significantly higher SPL.

Question 4: Is There Evidence of Functional Improvement in Communication Following LSVT-X?

Voice Handicap Index. Prior to treatment, the LSVT-X group's mean VHI score was 44 (*SD* = 22), a rating that is moderately correlated with an intermediate level of voice handicap (Jacobson et al., 1997). The posttreatment group mean fell to 30 (*SD* = 17), a drop into the mild self-rating category. This difference was not statistically significant ($p = .07$). Examination of individual scores showed that 4 of the 12 participants (33%) indicated significant improvement after treatment, each dropping his or her scores 31 points or more (according to Jacobson et al., 1997, a significant difference requires a reduction by a minimum of 18 points). Three of these participants maintained that improvement at follow-up; the fourth was not available for follow-up data collection. None of the 12 participants showed significant worsening on the VHI at posttreatment or follow-up evaluation (group mean for follow-up = 32, *SD* = 14).

Perceptual study. To determine interrater reliability, the scores of each of the four raters for all three treatment groups (i.e., 41 scores for each rater) were compared using intraclass correlation coefficient procedures. Though significant differences between the average scores of the raters were found, $F(3, 120) = 9.285$, $p < .001$, a significant intraclass correlation

TABLE 2. Changes in SPL following LSVT-X from pre- to posttreatment and follow-up for individual tasks.

Comparison	*M* (*SD*) dB SPL at 30 cm	Obtained *t* value	Significance (two-tailed)
Phonation			
Pre- vs. posttreatment	72.0 (6.3) vs. 83.0 (3.9)	10.12	<.001
Pretreatment vs. follow-up	72.0 (6.3) vs. 82.7 (4.7)	9.87	<.001
Posttreatment vs. follow-up	83.0 (3.9) vs. 82.7 (4.7)	–0.25	.805
Rainbow			
Pre- vs. posttreatment	72.7 (3.5) vs. 79.6 (3.3)	6.44	<.001
Pretreatment vs. follow-up	72.7 (3.5) vs. 78.7 (3.5)	5.61	<.001
Posttreatment vs. follow-up	79.6 (3.3) vs. 78.7 (3.5)	–0.84	.411
Picture			
Pre- vs. posttreatment	70.2 (2.7) vs. 77.2 (2.5)	6.57	<.001
Pretreatment vs. follow-up	70.2 (2.7) vs. 75.5 (3.1)	4.95	.001
Posttreatment vs. follow-up	77.2 (2.5) vs. 75.5 (3.1)	–1.62	.121
Conversation			
Pre- vs. posttreatment	69.6 (2.5) vs. 75.7 (2.6)	5.65	<.001
Pretreatment vs. follow-up	69.6 (2.5) vs. 73.7 (2.6)	4.14	.005
Posttreatment vs. follow-up	75.7 (2.6) vs. 73.7 (2.6)	1.79	.089

TABLE 3. Comparisons of LSVT-X SPL means before treatment with sample means from Ramig, Sapir, Fox, and Countryman (2001) representing estimates of two populations: a PD group prior to receiving treatment and a PD control group not receiving treatment.

Group comparison	*M* (*SD*) dB SPL at 30 cm	Obtained *t* value	Significance (two-tailed)
Pretreatment of T-PD	Est. population vs. X-PD		
Phonation	69.1 (5.1) vs. 72.0 (6.3)	1.56	.147
Rainbow	71.3 (3.2) vs. 72.7 (3.5)	1.35	.203
Monologue	69.0 (3.6) vs. 69.6 (2.5)	0.99	.344
Picture	68.9 (4.6) vs. 70.3 (2.7)	1.80	.099
Pretreatment of NT-PD	Est. population vs. X-PD		
Phonation	69.3 (4.1) vs. 72.0 (6.3)	1.45	.174
Rainbow	71.6 (3.6) vs. 72.7 (3.5)	1.05	.316
Monologue	69.3 (3.9) vs. 69.6 (2.5)	0.50	.626
Picture	70.4 (4.4) vs. 70.3 (2.7)	−0.18	.864

Notes. For all *t* tests reported above, *df* = 10, with the obtained *p* values evaluated against the adjusted alpha level of .0021 in order to be considered statistically significant.

coefficient was also found, Cronbach's $\alpha(40, 120) = 0.90$, $p < .001$, indicating that even though the raters differed in their criterion of "better," they observed the same relative changes in speech and voice from pretherapy to posttherapy to a high degree of agreement. Intrarater reliability was tested by having each rater score 20% of the pairs twice during the study. Pairs of scores were compared using the Pearson product–moment correlation coefficient. The average correlation coefficient was $r = .95$, with a range of .88 to .98, indicating a high degree of internal consistency within each rater.

Scores for the perceptual study were adjusted so that all final ratings reflected a presentation of pretreatment followed by posttreatment, regardless of the actual presentation. Therefore, if a speaker was given a score of –30 and the presentation of samples was pretreatment–posttreatment, it was not changed; if, however, the presentation was posttreatment–pretreatment, it was converted to +30. All adjusted scores above zero indicate better speech following therapy, and all negative scores indicate that speech sounded worse. Mean ratings and standard errors for the three groups are as follows: X-PD, $M = 19.3$, $SE = 4.3$; T-PD, $M = 20$, $SE = 4.0$; NT-PD, $M = 4.5$, $SE = 3.8$. Because there were significant differences between the mean ratings of the judges, a 3 × 4 mixed ANOVA was used to examine the magnitude of change in voice and speech between the groups (X-PD, T-PD, and NT-PD) while controlling for the differences across raters, the within factor. A significant main effect for treatment groups was found, $F(2, 38) = 5.02$, $p = .012$, $\eta = .21$. Post hoc comparison

TABLE 4. Comparisons of X-PD means after treatment and at 6 months to sample means from Ramig, Sapir, Fox, and Countryman (2001) representing estimates of two populations: a PD group after receiving treatment and a PD control group not receiving treatment.

Comparison	*M* (*SD*) dB SPL at 30 cm	Obtained *t* value	Significance (two-tailed)
T-PD posttreatment vs. X-PD posttreatment			
Phonation	82.4 (3.9) vs. 83.3 (3.9)	0.82	.429
Rainbow	77.9 (4.2) vs. 79.7 (3.3)	1.96	.076
Monologue	74.5 (4.0) vs. 75.8 (2.6)	1.86	.089
Picture	74.4 (4.3) vs. 77.3 (2.5)	4.34	.001*
T-PD follow-up vs. X-PD follow-up			
Phonation	79.8 (3.7) vs. 82.7 (4.7)	2.07	.065
Rainbow	76.1 (3.2) vs. 78.7 (3.5)	2.54	.030
Monologue	72.7 (3.6) vs. 73.7 (2.6)	1.44	.180
Picture	73.4 (3.7) vs. 75.5 (3.1)	2.39	.038
NT-PD posttreatment vs. X-PD posttreatment			
Phonation	70.5 (4.4) vs. 83.3 (3.9)	11.42	<.001*
Rainbow	71.9 (4.1) vs. 79.7 (3.3)	8.42	<.001*
Monologue	69.4 (3.9) vs. 75.8 (2.6)	8.99	<.001*
Picture	70.7 (4.1) vs. 77.3 (2.5)	9.86	<.001*
NT-PD follow-up vs. X-PD follow-up			
Phonation	70.6 (4.1) vs. 82.7 (4.7)	8.60	<.001*
Rainbow	71.9 (4.1) vs. 78.7 (3.5)	6.60	<.001*
Monologue	69.5 (3.2) vs. 73.7 (2.6)	5.88	<.001*
Picture	70.7 (4.1) vs. 75.5 (3.1)	5.49	<.001*

*Statistically significant as the obtained *p* value is less than the adjusted alpha level of .0021; for all *t* tests reported above, *df* = 10.

using Tukey *t* tests revealed that both treated PD groups differed significantly from the untreated control group: X-PD, $t(13.5) = 2.34$, $p = .035$; T-PD, $t(13.5) = 2.64$, $p = .02$. Results indicate that the speech of both treated groups was considered "better" following therapy, compared with the untreated group.

Discussion

The goal of this study was to evaluate whether LSVT-X, an extended version of LSVT, delivered over 2 months (rather than 1 month) with more home practice, can produce measurable speech and voice changes comparable to those typically seen following traditional LSVT. Results for this group of 12 participants indicate significant changes in vocal SPL following LSVT-X. These changes appear consistent with traditional LSVT when compared with population means from an earlier study (Ramig, Sapir, Fox, & Countryman, 2001). Participants receiving LSVT-X were also perceived as having "better" speech after therapy compared with before, and were not considered significantly different in this regard from participants who had received traditional LSVT. Finally, self-ratings using the VHI also suggest that on the whole, participants who received LSVT-X were less negatively affected by their voices following treatment and did not perceive decline over a 6-month period. Self-ratings of vocal improvement reached statistical significance at posttreatment and follow-up for at least 25% of participants. As the participants in the historical LSVT study did not complete the VHI, these results cannot be compared across studies.

The main differences between LSVT and LSVT-X are the distribution of the 16 treatment sessions over 2 months (versus 1 month), the amount of directed home practice, and the length of time between treatment sessions. Given that participants in the X-PD group received as much direct treatment as traditional LSVT clients, it is not entirely surprising that outcomes were similar. In fact, while the total face-to-face time with a clinician was equivalent, the length of time to consolidate new motor programs was twice as long and the amount of homework practice was more than twice as much for the LSVT-X group. This increased practice time may partially account for why participants in the X-PD group improved and compared favorably to the T-PD group from 2001 (Schmidt & Lee, 1999). The X-PD group had 8 weeks instead of 4 weeks for learning the target voice, with 2 weeks at each level of the hierarchy. In addition, the X-PD group practiced more than twice as much on their own (96 homework assignments compared with 40). These assignments also included individualized carryover communication tasks, thus increasing the opportunities for more specific practice and generalization over a longer period of time. Although in this study the members of the X-PD group did not perform significantly better than the historical LSVT group, the trend toward increasing vocal SPL from follow-up1 to follow-up2 in the X-PD group raises the question of whether target motor patterns might have been better established in this group.

It was somewhat surprising that the relative frequency of feedback did not appear to negatively affect the outcomes of the LSVT-X participants. During traditional LSVT, the clinician provides feedback for 4 consecutive days over 4 weeks, while LSVT-X allows for feedback every other day, twice a week, for 8 weeks. This has implications for the accuracy of home practice that could affect the acquisition of a new communication skill. Specifically, a potential disadvantage of reducing feedback early in therapy is the danger of not being able to easily shape a healthy loud target voice before the client returns home to practice for a day. The voice practiced in homework exercises must be the target voice taught in the clinical sessions for the client to be successful. The specificity of practice hypothesis states that when an individual performs movements repeatedly, a sensory representation is formed specific to the task (Coull, Tremblay, & Elliot, 2001). This hypothesis predicts that conditions of practice should closely approximate skills of retention. If homework or carryover activities are too different from the skill practiced, then there will not be a transfer of learning beyond the practice conditions. In addition, changes in central drive related to PD (Baker et al., 1998; Berardelli et al., 2001; Morris, Iansek, McGinley, Matyas, & Huxham, 2005) result in the person perceiving that he or she is speaking too loudly when he or she is speaking with normal loudness, which makes carryover of the target voice to homework even more challenging with a less frequent treatment schedule.

While the LSVT-X schedule may be attractive, there are practical considerations to bear in mind. In terms of efficiency, the long-term work load for both clinicians and clients is actually greater than typical LSVT and may result in more unbillable time or less clinical contact. Specifically, LSVT-X requires a total of 96 individual homework assignments, 56 more than regular LSVT. As taught in LSVT training workshops (Ramig & Fox, 2006), requirements for homework include hierarchical reading material, typically chosen to appeal to individual interests, and specific carryover activities per homework for each client at his or her current level (e.g., "Call your daughter and ask her three questions about her vacation in your loud voice"). Because preparation is not reimbursable, this leads to more unbilled time spent by clinicians gathering materials and creating carryover tasks to create the extra 56 homework assignments. Because home practice is considered an integral part of treatment, LSVT clinicians are instructed to spend a few minutes of each session checking the previous day's homework and describing the next assignment. With LSVT-X, a typical treatment session may include up to 5 homework assignments to check or prepare and explain. As a result, either LSVT-X sessions are increased in length to accommodate homework discussion without cutting into treatment time or practice time is reduced in order to stick to the schedule. Participants in the present study received the same amount of treatment as in traditional LSVT, and sessions often went longer to cover homework.

One recent study measuring service delivery variables related to LSVT (Wohlert, 2004) offers evidence to suggest that treatment may be altered further than the present study and still result in positive outcomes. In that study, treatment was provided at three different schedules to 11 people with PD (four times a week for 4 weeks, twice a week for 8 weeks, or twice a week for 4 weeks). Outcome measures included vocal SPL, maximum duration of sustained phonation, and pitch range following treatment and again 3 months later. The Sickness Impact Profile (Damiano, 1996) was also administered

as a functional measure of change. Results indicated that immediately following treatment, vocal SPL increased for all participants during reading and for all but 2 during sustained phonation. Three months later, most of these gains were substantially reduced. While results suggest positive immediate outcomes for different LSVT schedules, they cannot be easily compared with published LSVT efficacy studies due to significant differences in methodology. For example, 4 of 11 participants chose their preferred group due to transportation issues, resulting in incomplete randomization. This method also produced unbalanced groups, with 3 in the 4 × 4 group, 2 in the 2 × 8 group, and 6 in the 2 × 4 group. There were also significant differences in data collection. In contrast to other LSVT studies, participants in this study were cued to phonate loudly before and after treatment, and so spontaneous gains in vocal SPL could not be accurately measured after treatment. Furthermore, treatment was administered by graduate students who were supervised by a certified LSVT clinician, but not certified themselves. It is therefore difficult to draw conclusions about which variables affected the outcome.

Readers should bear in mind several limitations of the current study as well. Although the use of historical data for comparison is not uncommon, further study with concurrently collected control data is recommended to avoid potential measurement error and differences in medical care that may have influenced the groups in unpredictable ways. Also, because the LSVT-X group was led to believe there were two different treatment schedules available, while the LSVT group was not, the two groups were not completely randomized and may have had different expectations.

There is a clear need for more and varied ways to administer LSVT, or any efficacious treatment, so the greatest number of people can benefit from speech-language pathology services. However, the need to increase accessibility of treatment ought to be tempered by the greater need to maintain efficacy of treatment protocols (Trail et al., 2005). Although principles such as intensity of motor training have long been accepted in terms of behavioral recovery and improved function, only recently have the neurobiological phenomena underlying such principles been stringently validated for the positive effects on central nervous system functioning (Cotman & Berchtold, 2002; Kleim et al., 2003; Vaynman & Gomez-Pinilla, 2005). Thus, efforts are ongoing to develop creative technologies that provide greater access at lower cost without disrupting the intensity or frequency of treatment. Recent advances include technologies that allow clients to receive treatment from a clinician at a distance (e.g., telemedicine; Hill & Theodoros, 2002; Mashima et al., 2003), as well as computer devices that help administer treatment and collect data. Devices include the LSVT Companion (LSVT-C; Halpern et al., 2004), a specially programmed personal digital assistant (PDA) that is designed to help clients work independently and collect data for speech-language pathologists to assess therapy progress. Preliminary results from a study of this device indicate that participants of various ages and with little or no computer experience can use the LSVT-C successfully and, when used for a portion of their 16 treatment sessions, make gains in vocal SPL comparable to those reported in previous studies (Ramig, Sapir, Fox, & Countryman, 2001). Also in development is the LSVT Virtual Therapist (Cole, Ramig, Yan, Halpern, & Van Vuuren, 2004), a computerized therapist based on live clinical models, which guides therapy, provides real-time feedback, and collects performance data. Both computer devices are intended to respond to a client's individual needs and can be programmed to meet specific goals. Neither device is meant to replace a trained clinician. Rather, they are intended to complement traditional LSVT so that some sessions out of the total of 16 can be conducted at home with the aid of technology.

Future research should continue to examine ways to make treatment more accessible, more efficient, and more effective. While LSVT-X is promising, further study is needed with larger subject groups, simultaneous controls, and data collection out to 2 years, to truly establish efficacy that is comparable to LSVT. Additional areas for research include other possible treatment schedules, the effects of different feedback schedules, and examination of facial expression, speech articulation, and swallowing, all of which appear to change following traditional LSVT.

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Contact author: Jennifer Spielman, National Center for Voice and Speech, 1101 13th Street, Denver, CO 80204.
E-mail: jspielman@dcpa.org.

Leslie Mahler is now at the University of Rhode Island.

Appendix

Traditional Lee Silverman Voice Treatment (LSVT) Versus Extended Version (LSVT-X) Treatment and Homework Schedule

LSVT (four 1-hr sessions per week)	LSVT-X (two 1-hr sessions per week)
Week 1: drills plus words and phrases Week 1 homework = 10 assignments	Week 1: drills plus words and phrases Week 1 homework = 12 assignments
Week 2: drills plus sentences Week 2 homework = 10 assignments	Week 2: drills plus words and phrases Week 2 homework = 12 assignments
Week 3: drills plus paragraph reading Week 3 homework = 10 assignments	Week 3: drills plus sentences Week 3 homework = 12 assignments
Week 4: drills plus conversation Week 4 homework = 10 assignments	Week 4: drills plus sentences Week 4 homework = 12 assignments
Total homework assignments = 40	Week 5: drills plus paragraph reading Week 5 homework = 12 assignments
	Week 6: drills plus paragraph reading Week 6 homework = 12 assignments
	Week 7: drills plus conversation Week 7 homework = 12 assignments
	Week 8: drills plus conversation Week 8 homework = 12 assignments
	Total homework assignments = 96

Note. Homework is done for 5-10 min once on treatment days and 10-15 min twice (each time) on no-treatment days. Each homework assignment includes individual carryover activities for that day, as well as individualized readings for the hierarchy level.