

Effect of the Lee Silverman Voice Treatment (LSVT®) on Articulation in Speakers with Parkinson's Disease

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The purpose of this study was to evaluate the effects of LSVT® upon articulation in people with Parkinson's disease (PD). Four individuals diagnosed with idiopathic PD participated in the study. All participants exhibited mild or moderate hypokinetic dysarthria and spoke New Zealand English as their first language. Participants were asked to complete a speech reading task twice prior to, and twice following treatment. Measures of relative vocal intensity and acoustic measures of articulation, including voice onset time (VOT) and vowel formant frequencies were examined pre- and post-treatment. Results indicated that vocal loudness increased significantly following LSVT® which appeared to facilitate changes in consonant and vowel articulation. The observed changes to the acoustic measures of articulation post-treatment suggest that treatment with LSVT® may facilitate improved speech articulation in individuals with PD.

Parkinson's disease (PD) is a slowly progressive neurological disorder. It occurs as a result of damage to the basal ganglia control circuits within the brain and involves the progressive degeneration of dopamine producing neurons in the substantia nigra. The primary function of the basal ganglia is to control movement; therefore, pathology in this area affects the execution of movement. Specifically, damage to the basal ganglia control circuits reduces amplitude of movement and impairs the ability to inhibit involuntary movement

(Fahn, 1995). Impaired movement is observed in the speech mechanism of individuals with PD. Studies estimate that as the disease progresses, between 75% and 89% of individuals with PD will develop a speech disorder (namely hypokinetic dysarthria) (Fox, Morrison, Ramig, & Sapir, 2002). Oxtoby (1982) reported that hypokinetic dysarthria in individuals with PD was responsible for some of the most embarrassing, upsetting, and isolating aspects of the disease itself. Both patients and their families commonly report

that the impaired ability to communicate is one of the most debilitating aspects of PD (Fox et al., 2002). Consequently, the importance of effective speech treatment programmes for this population cannot be underestimated.

In 1988, the Lee Silverman Voice Treatment (LSVT®) was developed to address the speech deficit observed in PD (Fox et al., 2002). In general, the aim of LSVT® is to increase respiratory drive for speech and improve vocal fold adduction (Ramig, Bonitati, Lemke, & Horii, 1994); consequently improving voicing and intelligibility levels. LSVT® is based upon five essential concepts: (1) exclusive focus on voice, (2) stimulation of high-effort productions with multiple repetitions, (3) intensive delivery of treatment, (4) enhancing sensory awareness of increased vocal loudness and effort, and (5) quantification of behaviours (Fox et al., 2002). Treatment is delivered intensively, employing four 60-minute sessions per week for four consecutive weeks.

A review of the published research investigating the efficacy of the LSVT® programme reveals a large body of evidence supporting the use of this treatment for improving vocal loudness in people with PD. A series of randomised controlled clinical trials comparing groups of participants who had received LSVT® to those who had received an alternative treatment emphasising high respiratory effort (RET) have all demonstrated that LSVT® results in significantly improved loudness levels (Ramig, Countryman, O'Brien, Hoehn, & Thompson, 1996; Ramig, Countryman, Thompson, & Horii, 1995; Ramig et al., 2001). Follow-up studies revealed that the increased loudness levels following LSVT® were effectively maintained for up to one and two years post-treatment (Ramig et al., 1996; 2001). Studies have also observed improvements to the perceptual features of voicing production following LSVT® (Baumgartner, Sapir, & Ramig, 2001; Ramig et al., 1995, 1996; 2001; Sapir et al., 2002) with one study reporting gains that were maintained up to one year post-treatment (Sapir et al., 2002).

Based upon studies conducted thus far, it is now generally accepted that LSVT® results in improved loudness and voice quality for people with PD. However, reduced loudness and impaired voice quality are not the only salient characteristics of hypokinetic dysarthria. A prominent feature of the disorder is articulatory impairment; specifically, distortion of consonants (Ackermann & Ziegler, 1991; Logemann & Fisher,

1981; Logemann, Fisher, Boshes, & Blonsky, 1978; McAuliffe, Ward, & Murdoch, 2005, 2006; Weismer, 1984). As imprecise articulation has a significant impact on the intelligibility of speech, it is a crucial aspect to address in speech therapy treatment programmes for people with PD.

Research has recently suggested that LSVT® may improve speech articulation in individuals with PD. Fox et al. (2002) commented that "vocal loudness training may stimulate increased amplitude and coordination of motor output (beyond the phonatory system) to the orofacial system" (p. 113). However, limited empirical research has been completed to support this contention. Dromey, Ramig, and Johnson (1995) examined both phonation and articulation in a 49 year-old male with PD before and after LSVT® and documented increases in vowel duration, whole word duration, transition duration, and transition extent during single word productions following treatment. Decreased fricative duration and spectral rise time were also reported. Collectively, these changes were hypothesised to reflect improvements in the inter-articulatory coordination of speech.

A recent study by Sapir, Spielman, Ramig, Story, and Fox (2007) investigated the effect of LSVT® on vowel articulation. Twenty-nine individuals with PD were randomly assigned to a treatment (LSVT®) or a non-treatment group and compared to fourteen healthy controls. Acoustic measures of vowel articulation and perceptual ratings of vowel production were conducted. Prior to treatment, significant differences between the patients and the healthy controls were found on measures of vocal sound pressure level, the second formant frequency (F2) of /u/, and formant ratios for /i/ and /u/. All acoustic variables and perceptual ratings underwent statistically significant changes in the group who received LSVT® treatment only. As these changes were in the direction of normal values, the authors concluded that they indicated improved vowel articulation following LSVT®.

In contrast to the large body of research investigating phonatory outcomes following LSVT®, research examining the direct effects of the programme upon speech articulation in the PD population is limited. While the study by Dromey et al. (1995) examined articulation in one individual only, and the study by Sapir et al. (2007) examined vowel articulation only, both suggest that LSVT® may indirectly affect consonant and vowel articulation in individuals with PD. The purpose of the present study was to evaluate the influence of

LSVT® upon the speech articulation of consonants and vowels in people with PD. It was hypothesised that LSVT® would serve to change selected features of consonant and vowel articulation.

METHOD

Participants

The participant group consisted of four individuals, three males and one female, diagnosed with PD by a neurologist. The mean age of the group with PD was 65 years (SD = 9 yrs) with an age range of 54 to 72 years. All participants spoke New Zealand English as their first language. Specific biographical and medical details of the participants with PD are located in Table 1. Individuals were referred to the programme by their treating neurologist and all provided written consent for participation. Prior to undertaking LSVT® all participants underwent fiberoptic laryngoscopy, completed by an otolaryngologist and a speech-language therapist (SLT), to ensure that pathological changes of the larynx were not responsible for the participants' voice disorder. Individuals were considered appropriate for participation in the study if they exhibited idiopathic PD and a speech diagnosis of hypokinetic dysarthria and had stable medical regimens during the assessment and treatment periods. Participants were excluded from the study if they had: (1) any history of neurological disorder with the exception of PD, (2) undergone any form of neurosurgical procedure for the treatment of PD, (3) not completed all 16 session of LSVT® treatment, (4) a history of speech disorder with the exception of that resulting from PD, or (5) prior history of surgery involving the lips and/or tongue. Participants exhibited mild or moderate hypokinetic dysarthria as rated by a SLT experienced in the assessment of dysarthria.

Treatment

All four participants completed 16 sessions of LSVT® over a four-week period. Final year speech and language therapy students, under the close supervision of two qualified LSVT® clinicians, administered LSVT® as per treatment guidelines. Each session was 50 minutes in duration. For details of treatment tasks and an outline of the rationale for LSVT®, readers are directed to Ramig et al. (1995).

Data Collection

Data were collected on two occasions prior to LSVT® treatment and on two occasions following treatment. Data collection sessions were conducted at the same time of day for each participant. Due to clinical scheduling constraints, the pre-treatment sessions were undertaken on two non-consecutive days (with one rest day between the two assessment sessions) and the post-treatment sessions on two consecutive days. During each session, participants were asked to read aloud a list of nine target CVC words that were recorded for later analysis. Target words included: keep, cart, coop, peat, part, poot, teat, tart, and toot. The experimental speech task involved production of the target words (presented in a random order) and repeated five times each (to a total of 45 words per assessment). Target words were preceded by /ə/, resulting in a "/ə/ CVC" speech sample for analysis. The stop consonants /k/, /t/, and /p/ were chosen for investigation based on prior research in PD that noted a higher concentration of articulatory errors in the stop consonants irrespective of voicing (Logemann & Fisher, 1981). Therefore, only one variant of the stop consonant (the voiceless stop) was selected for examination. The vowels /i/, /a/, and /u/ were investigated as they cover high-front, high-back, and low-back features of tongue articulation.

Table 1: Biographical and medical details of the four participants with Parkinson's disease.

Participant	Gender	Age (Yrs)	Years post- diagnosis	Dysarthria severity	Medication
P1	Male	63	2	Mild	Pergolide, Mesylate
P 2	Male	72	7	Mild	Madopar, Pergolide
P 3	Male	72	8	Moderate	Sinemet
P 4	Female	54	5	Mild	Sinemet

Audio recordings were completed in a quiet room. The acoustic signal was recorded onto a digital minidisk recorder (Sony M2-NHI) at 44kHz (non-compression mode). A uni-directional electret condenser microphone (Sony ECM-M5907) was placed on the table in front of the participant at a mouth-to-microphone distance of 30cms. Data obtained were transferred digitally to a personal computer for acoustic analysis.

Acoustic Analysis

Acoustic analysis was completed using PRAAT acoustic analysis software version 4.3.12 (Boersma & Weenink, 2005). The specific consonant and vowel articulation measures performed are detailed below.

Voice Onset Time (VOT)

VOT was selected to provide a temporal measure of change to consonant articulation following LSVT®. The initial consonant portion of each word was subjected to analysis using an amplitude-by-time waveform. Duration of VOT was measured from the beginning of the plosive burst to the onset of periodicity associated with the subsequent vowel (Lisker & Abramson, 1964). VOT was calculated separately for each of the three consonants (/k/, /p/, and /t/) resulting in a total of 15 repetitions of each consonant per participant at each assessment session. Each individual's average VOT across the two pre- and post-treatment sessions was used in the statistical analysis of results.

Vowel Formants

Vowel articulation was examined through calculation of the first (F1) and second formant (F2) frequency. The F1 and F2 frequency of each vowel was determined by a 50 ms (milliseconds) window placed at the midpoint of the vowel steady state. Standard PRAAT settings (five formant bands with the highest frequency set at 5000 Hz) were employed and provided an automatic estimate of each F1 and F2 frequency. As different formant patterns characterise different vowels, the three vowels /a/, /i/, and /u/ were analysed independently. Each participant's average F1 and F2 frequency over the two pre- and post-treatment sessions was employed in the statistical analysis.

Relative Vocal Intensity

As the goal of LSVT® is to increase loudness, this particular acoustic variable was included to determine whether the current treatment did indeed result in increased loudness for the four

participants. Given the known effects of increased loudness upon articulation in normal speakers (Schulman, 1989), this information was considered important to the subsequent interpretation of the results of the study. Relative vocal intensity was calculated over the duration of the whole word production. Vertical cursors were placed at the onset of the stop burst and at the cessation of acoustic energy associated with the word-final consonant. The PRAAT software provided an estimate of relative intensity (dB) for each word production. Each participant's average intensity over the two pre- and post-treatment sessions was employed in the statistical analysis.

Reliability of Acoustic Measures

Re-analysis of 25% of the data set (one participant's data) was conducted to provide a measure of reliability. To determine intra-judge reliability, the investigator who performed the initial measurements also performed the second set of reliability measures. To determine inter-judge reliability, an investigator not involved in the original analysis performed the second set of measures. Spearman's correlation coefficients and absolute difference measures were used to index reliability between the first and second set of measures. For VOT, the correlation between the first and second set of measures was 0.99 and the absolute difference measure was 4 milliseconds (ms) for both intra-judge and inter-judge reliability. The correlation between the first and second set of data for all vowel measures was 0.99. Absolute difference was calculated at less than 2 Hz for both intra-judge and inter-judge reliability for measures of F1, and at 10 Hz for both intra- and inter-judge measurement of F2. Finally, intensity measures yielded a correlation score of 0.99 for intra-judge and 0.97 for inter-judge reliability. The absolute difference measure of intensity was less than 1dB for both intra- and inter-judge reliability.

RESULTS

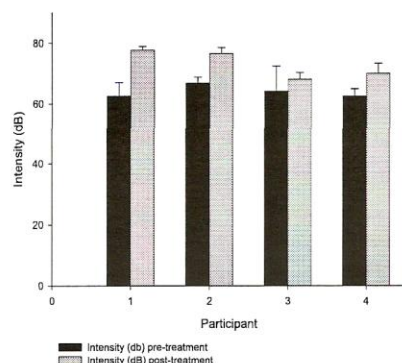
Given the repeated measures experimental design, normal distribution of data, and its conformity to the assumption of homogeneity of variance, paired *t*-tests (at $p < 0.05$) were used to determine if statistically significant differences existed for the group pre- and post-treatment. Individual participant results were then considered on a case-by-case basis.

Relative Vocal Intensity

Figure 1 contains individual participant data for

relative intensity. As a group, the mean relative intensity of word production increased from 65 dB pre-treatment to 73 dB post-treatment [$t = -4.74, p = 0.02$]. Inspection of individual results indicated that all participants exhibited clinically significant increases in intensity of greater than five dB.

Figure 1: Changes to intensity following treatment for the four individual participants.



Voice Onset Time

Figure 2 contains the results of VOT analysis. As a group, VOT was found to decrease for all consonants following treatment. Statistical analysis indicated a significant reduction in VOT for /k/ [$t = 3.96, p < 0.05$] and /t/ [$t = 3.10, p = 0.05$] following treatment. The reduced VOT for /p/ observed following treatment was not statistically significant [$t = 2.98, p > 0.05$]. Visual analysis of individual results indicated that all participants in the group demonstrated reduced VOT for /t/ and /k/. For /p/, three of the four participants exhibited reduced VOT post-treatment.

Figure 2a: VOT results for /p/

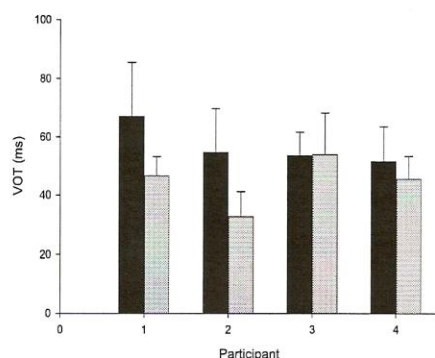


Figure 2b: VOT results for /t/

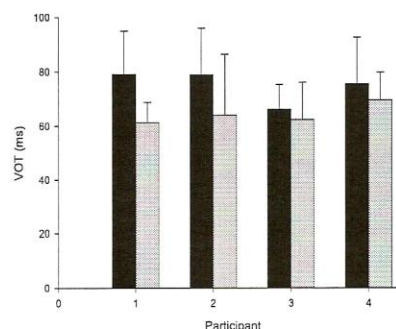
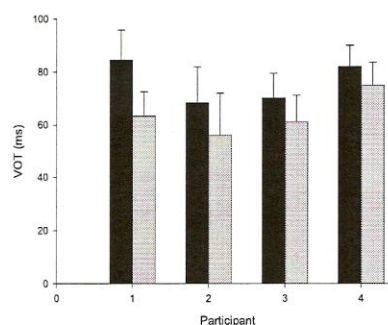


Figure 2c: VOT results for /k/



Vowel Formants

Results of the vowel formant analysis are presented in Table 2. Group data revealed a significant reduction in F2 frequency for /u/ [$t = 3.80, p < 0.05$] following LSVT®. All remaining comparisons for both F1 and F2 frequency for each vowel were not significant ($p > 0.05$). Visual inspection of individual results revealed a clear trend of increased F1 following treatment across all participants. The results for F2 were less consistent. P1 and P3 demonstrated decreases in F2 values across all vowels post-treatment. In contrast, both P2 and P4 demonstrated increased F2 frequency for /i/ and /a/ and decreased F2 frequency for /u/ post-treatment.

DISCUSSION

While numerous studies have demonstrated that LSVT® results in increased loudness and improved vocal quality in individuals with PD, there has been limited investigation of its effect on articulation. This study used acoustic analysis to investigate the effect of LSVT® upon articulation in individuals with PD. Consistent with prior research, significantly increased speech intensity was demonstrated following treatment in the group of four individuals with PD. In regards to the acoustic

Table 2: Mean and standard deviation for F1 and F2 (in Hz) across the three vowels for the four individual participants

Participant	Vowel	F1		F2	
		Pre-LSVT®	Post-LSVT®	Pre-LSVT®	Post-LSVT®
P1	/i/	391 (27)	449 (23)	2081 (92)	2065 (157)
	/a/	649 (32)	739 (18)	1590 (51)	1409 (86)
	/u/	421 (52)	466 (32)	1711 (102)	1619 (85)
P2	/i/	309 (20)	423 (21)	2065 (138)	2093 (72)
	/a/	712 (88)	675 (84)	1663 (64)	1724 (62)
	/u/	315 (19)	423 (16)	1810 (53)	1777 (43)
P3	/i/	348 (30)	360 (25)	2280 (159)	2172 (124)
	/a/	748 (57)	776 (23)	1514 (69)	1501 (55)
	/u/	348 (37)	375 (18)	1886 (162)	1837 (97)
P4	/i/	418 (93)	419 (19)	2950 (205)	3084 (169)
	/a/	750 (148)	870 (34)	1749 (85)	1757 (104)
	/u/	414 (24)	448 (30)	2167 (95)	2144 (65)

analysis, subtle changes to articulation including significant reductions in VOT and a general trend towards increased F1 for all vowels were revealed.

The finding of reduced VOT across all consonants for the participant group is thought to reflect the influence of increased loudness upon articulator movement. To date, studies have not examined changes to VOT following LSVT®; however, previous studies investigating the effect of loudness upon articulator movement in neurologically healthy speakers provide a basis for interpretation of the present findings (Dromey & Ramig, 1998; Schulman, 1989; Wohlert & Hammen, 2000). Schulman (1989) undertook simultaneous recordings of lip and jaw movement and the accompanying audio signal and found that loud speech, when compared to normal speech, was characterised by greater lip opening, tighter lip compression, faster lip movement, and shorter durations of production of bilabial stops. Dromey and Ramig (1998) also found that increased loudness was associated with increased speed and amplitude of both upper and lower lip movements. Using EMG amplitude analysis, Wohlert and Hammen (2000) reported that loud speech was associated with higher average lip movement amplitudes, whereas soft speech was associated with lower average lip amplitudes. It is hypothesised that with

increased loudness, the reduction in VOT observed in the current study reflects two things: increased speed of movement of both the lips and tongue during articulation and the completion of these movements with more forceful contact (labial-labial and lingual-palatal). If the muscles come together and move apart at a faster rate, stop closure is achieved more quickly, a result that is likely to be reflected acoustically by reduced burst duration.

While overall the results of the current study revealed a reduction in VOT for consonant production following LSVT®, when individual consonants were examined, only the velar stop /k/ demonstrated a significantly reduced VOT. Previous research has shown that in individuals with mild to moderate hypokinetic dysarthria, the velar stop /k/ is generally the first consonant sound affected by the disease process and the most severely distorted (Logemann et al., 1978). Logemann et al. (1978) observed that as the severity of articulatory impairments increased, individuals were more likely to produce errors in the consonants that require anterior vocal tract placements (i.e., /t/ or /p/). Therefore, it is not surprising to find that VOT of /k/ was the most amenable to change following LSVT® treatment.

The results also revealed a general increase in F1 following treatment for all vowels. In contrast,

the results for F2 were less consistent. The F1 results provide evidence of the effect of increased loudness on formant frequencies during vowel production. Interpretation of the current findings is offered by examination of acoustic theories. In theory, the frequency of F1 is raised by a constriction of the pharynx and a decrease in constriction of the anterior vocal tract (Baken & Orlikoff, 2000). Beginning with pharyngeal constriction, it is possible that increased loudness in the present group of participants may have resulted in increased movement of the pharyngeal constrictor muscles post-LSVT®. However, it is considered more likely that the trend towards increased F1 was a direct consequence of reduced constriction of the anterior vocal tract that resulted from increased jaw opening during speech production post-treatment. This theory is supported by previous studies of neurologically normal speakers which have reported that increased loudness is associated with greater displacement of the jaw during speech production (Geumann, 2001; Schulman, 1989) and that increased jaw opening is correlated with increased F1 (Geumann, 2001; Titze, 1994).

Overall, the study yielded inconsistent results for F2. However, one finding was consistent: all individuals demonstrated a decrease in F2 for /u/ post-LSVT®. This finding was supported by Sapir et al. (2007) who also found significant changes in the value of F2 for /u/. Again, acoustic rules governing articulation are used to provide further interpretation of these findings. It is generally accepted that the frequency of F2 is lowered by constriction of the posterior tongue and increased lip rounding (Baken & Orlikoff, 2000). Therefore, it is hypothesised that increased loudness in the current group of participants resulted in increased constriction of the posterior tongue and increased lip rounding during production of /u/. This is supported by previous research that has reported evidence of a relationship between increased loudness and increased labial movements (Dromey & Ramig, 1998; Schulman, 1989; Wohler & Hammen, 2000). Sapir et al. (2007) also commented that the decrease found in the F2 value of /u/ is likely to reflect increased lip rounding. While studies have not previously reported a relationship between increased constriction of the posterior tongue and increased loudness, it is thought that with the increased effort required to produce loud speech, such movement is likely. Whereas the F2 value for /u/ decreased following treatment for all participants, the changes to the

F2 values for both /i/ and /a/ were inconsistent. Post-LSVT®, two participants demonstrated an increased F2 value for /i/ and /a/ and two participants demonstrated a decreased F2 value. Aside from the limitation due to small participant numbers, consideration of the articulatory postures required for the articulation of each of the individual vowels may assist in understanding the current findings. The three vowels /a/, /i/, and /u/ are termed point vowels, as their production relates to extremes positions of oral tract constriction. Specifically, /a/ entails the most pharyngeal and open jaw movement, /i/ the most anterior tongue and lip spread movement, and /u/ the most back tongue and lip rounded movement. Therefore, it seems logical that the movement of the specific articulatory structures would change only during production of vowels for which their particular movement was necessary. As such, findings of lowered F2 values, which decrease with increased movement of the posterior tongue and lip rounding, would be expected only for /u/.

In summary, the current study revealed evidence of acoustic articulatory changes following LSVT® in a group of four individuals with mild and moderate hypokinetic dysarthria. While the current findings were interpreted to indicate that LSVT® facilitated increased movement of the articulatory muscles and, therefore, improved articulation in the group, limitations of the study necessitate that these results be interpreted with caution. Small participant numbers, lack of a control group, the absence of supporting perceptual data, and examination of consonant production in a single word environment only are obvious limitations to this study. However, the current evidence for treatment of articulation impairments in individuals with PD is sparse. The present study, therefore, represents a valuable first step towards increasing this literature base. Additionally, a treatment programme that entails treating one component of speech production and facilitating gains in another holds much relevance when treating people with PD.

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