ORO-FACIAL CHANGES IN PARKINSON’S DISEASE FOLLOWING INTENSIVE VOICE THERAPY (LSVT®)

Jennifer L. Spielman¹, Lorraine O. Ramig¹,², Joan C. Borod³

¹Wilbur James Gould Voice Center
The Denver Center for the Performing Arts
jspielman@dcpa.org, ramig@spot.colorado.edu

²Department of Speech, Language and Hearing Sciences
University of Colorado, Boulder

³Queens College of the City University of NY, and
Department of Psychology, Mount Sinai School of Medicine
Joan.borod@mssm.edu

ABSTRACT
Parkinson’s disease (PD) is associated with multiple communication deficits which affect both verbal and nonverbal abilities, including vocal loudness, articulatory precision, and facial expression. This paper addresses the effects of intensive voice therapy (Lee Silverman Voice Treatment®, LSVT) on communicative acts in PD involving significant oro-facial movement, specifically speech articulation and spontaneous facial expression. Both acoustic measurements and perceptual judgments are presented. The underlying mechanisms thought to be responsible for treatment-related changes are proposed and discussed.

1. INTRODUCTION
Parkinson’s disease (PD) – a progressive neurological disorder of the basal ganglia – can affect interpersonal communication in a variety of ways. In addition to well-defined voice and speech characteristics which include a soft, monotone, breathy voice and imprecise speech articulation [1], individuals with PD typically exhibit a “masked” or immobile face which can interfere with the spontaneous expression of emotion [2]. The communication disorder is often compounded by a lack of awareness of one’s speech and voice deficits, possibly relating to faulty sensory feedback. For years, the treatment of communication disorders in PD was typically unsuccessful.

Recent advances in behavioral treatment of voice and speech in PD demonstrate that therapy focusing on increasing vocal loudness predictably improves communication in a number of areas. Studies examining voice and speech in PD before and after the Lee Silverman Voice Treatment®, or LSVT [3], have reported improvements in vocal loudness, voice quality, speech intonation, laryngeal muscle activity and aerodynamics. More recently, improvements in speech articulation and spontaneous facial expression have been observed, suggesting a global impact of LSVT on communicative output. This paper summarizes findings from two different studies which examined pre-post LSVT changes in communication specifically implicating oro-facial movement (articulation and facial expression), and discusses the underlying mechanisms which may help explain these treatment-related changes.

2. COMMUNICATIVE CONSEQUENCES OF FACIAL IMMOBILITY IN PD
Both verbal and nonverbal communication can be affected by diminished facial expression accompanying PD. The effects on nonverbal, emotional expression include both a reduction of general facial mobility as well as specific involvement of the upper facial muscles, often leading observers to ascribe negative personality traits to these individuals. Of greater concern is the potential for misdiagnosis of PD, which may be mistaken for clinical depression based on flat facial affect [4].

In terms of verbal communication, reduced movement of facial muscles – particularly the tongue, jaw and lips – can contribute to decreased vocal loudness and imprecise articulation. It has also been suggested that facial expressions may “structure the acoustical signal in a consistent fashion” [5, p. 2106], shaping the harmonics of the source signal to communicate facial configurations expressive of certain states (e.g., smiles, frowns). The interaction between voice source, vocal tract, and upper articulators is potentially reflected in vowels, which can be measured acoustically for loudness (SPL), pitch (F0), and articulatory accuracy (F1, F2).

Two separate studies will be presented to address these issues. One study involved the acoustic analysis of vowels produced by individuals with PD before and after receiving the LSVT, compared to both PD and healthy control groups. The other study used trained observers to examine aspects of facial movement and expression in two groups of individuals with PD who received different types of treatment. While these studies are quite distinct, both address the question of whether intensive voice therapy alone can drive changes in communication which were not the focus of treatment.
3. STUDY #1: VOWEL SPACE IN PD

Reduced vowel space has been documented in the speech of individuals Parkinson’s disease [6], and may be associated with decreased speech intelligibility. Clinical approaches used to improve speech intelligibility include reducing rate and increasing vocal loudness, both of which appear to expand vowel space. However, there is evidence that rate reduction does not necessarily lead to listener perceptions of improved intelligibility or decreased severity of dysarthria, making its practical application questionable.

Recently, it was found that the LSVT had a positive impact on vowel space and speech intelligibility for a subject with ataxic dysarthria [7]. The purpose of the present study was to examine the effects of the LSVT on vowel formant frequencies and vowel space in a group of subjects with Parkinson’s disease.

3.1. Subjects

Thirteen male subjects with Parkinson’s disease were recruited and randomly assigned to either a treatment (PDTx, n = 6) or non-treatment (PDU, n = 7) group. Six additional subjects acted as neurologically normal controls (HC, n = 6). The LSVT was administered to members of the PD Tx group as described elsewhere [3].

3.2. Methods

Acoustic data were collected in a sound-treated booth, three times within the week before treatment and twice immediately following treatment. Vowels /i/, /u/ and /a/ were extracted from multiple productions of standard sentences (“The blue spot is on the key,” “The potato stew is in the pot,” and “Buy Bobby a puppy”), for a total of 9 pre-treatment tokens of each vowel and 6 post-treatment tokens per subject. Formant frequencies (F1 and F2) were tracked using an LPC technique (autocorrelation method) with a window length of 50 msec and a 12.5 msec overlap. (F1, F2) pairs were averaged and vowels were plotted in F1-F2 space to create vowel triangles. The area of each subject’s pre and post-treatment vowel triangle was calculated to determine vowel space.

3.3. Results

Prior to treatment, both PD groups exhibited decreased vowel space compared to the HC group, vowel space for the PD Tx group being significantly smaller than the HC group (p < .025). Following treatment, only vowel space for the PD Tx group increased significantly (t = 4.99, p = .008), and was no longer smaller than the HC group (F = 0.2, p = .67) (figure 1).

Mean pre-treatment vowel formant frequencies for each group revealed a more centralized articulation for both PD groups, reflected in reduced F2 for /i/, increased F2 for /u/, and reduced F1 for /a/ compared to the HC group. Following LSVT®, the PD Tx group showed significant changes in vowel formant frequencies while the other two groups remained stable. Paired pre-post t-tests within the PD Tx group indicated that for the /i/ vowel, both F1 and F2 increased significantly (p = .012 and p = .023, respectively), and F1 increased for /a/ (p = .006). Additionally, F2 for /u/ showed a near-significant decrease (p = .058) (figure 2).

4. STUDY #2: FACIAL EXPRESSION IN PD

As noted above, the masked facial expression associated with PD can have serious social and medical consequences for these individuals. Historically, deficits in facial expression in PD have been even more challenging to treat than speech and voice. However, there is some preliminary evidence that intensive voice therapy can positively impact facial expressivity in these individuals [8]. The purpose of the present retrospective study was to examine in greater detail the effects of the LSVT on facial expression in individuals with PD.

4.1. Subjects

Forty-four individuals with idiopathic Parkinson’s disease were stratified based on age, sex, stage of disease, rating on the Unified Parkinson’s Disease Rating Scale (UPDRS), time since...
diagnosis, degree of glottal incompetence, and severity of speech deficit and then randomly assigned to either a voice treatment group (LSVT, \( n = 26 \)) or a respiratory treatment group (RT, \( n = 18 \)). Intensive voice therapy was administered to members of the LSVT group as described elsewhere [3]. During this study, no direct attention was given to facial expressivity. A contrasting respiratory treatment (RT) was designed as a control to imitate the LSVT in principle, with the focus on maximizing respiratory support for speech without attention to vocal loudness. Both treatments were administered with the same skill and enthusiasm by the same clinicians.

4.2. Methods

All subjects were videotaped once within a week prior to therapy, and again within a week following therapy. Stimuli for the study were extracted from 20 seconds of extemporaneous speech produced during a self-generated monologue or a semi-structured interview. Six native female raters (mean age = 28.14 years; \( sd = 8.17 \) years) were trained extensively to judge the subjects’ faces on three experimental variables: **mobility**, **engagement**, and **positive emotion**. Pre- and post-treatment video segments were paired for each subject, randomized across treatment condition (pre vs. post) and group (LSVT vs. RT), and then presented without sound. For each pair of video segments, raters were asked: 1) which of the faces is more X? and 2) how much more X is that face? Question number two was graded on a scale of 1-5, where 1 = “minimally” and 5 = “extremely”. Thus, each subject was compared to himself before and after treatment, and rated on degree of expressivity. Scores for each subject were tallied across raters and an intraclass correlation coefficient was calculated to determine reliability.

4.3. Results

Intraclass correlation coefficients for all variables ranged from .87 to .90, expressing a high degree of inter-rater reliability. Overall, observers considered the LSVT group more facially expressive after treatment than before, compared to the respiratory group (table 1). Fisher’s Exact Tests revealed no significant differences between the two groups, but a number of trends appeared. Further binomial testing revealed that members of the LSVT group were rated significantly more facially mobile (\( p \leq .015 \)) after treatment compared to before.

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*Table 1: Individuals from each treatment group categorized on the basis of facial mobility, engagement and positive emotion over treatment condition.*

Comparing 5-point scale means across groups, the LSVT group again appeared significantly more facially expressive than the RT group, although none of the differences were significant.

5. DISCUSSION

5.1. Vowel Space Changes Following Treatment

In the present study, changes in all three corner vowels contributed to an expansion of vowel space in all members of the treated PD group. This is in contrast with rate-related increases in vowel space in amyotrophic lateral sclerosis (ALS) reported by Turner et al. [9], who found that only 4/9 subjects increased vowel space with reduced rate and that only 2/4 vowels contributed to the change.

To examine whether changes in format frequency might have been caused by reduced rate accompanying loudness increases, follow-up duration measurement of vowels /a/ and /u/ were made for the treated group. Duration for /a/ appeared consistently but insignificantly longer following treatment, while a significant increase in duration for /u/ was revealed (\( p < .02 \)). These results are difficult to interpret. However, as the present study drew no attention to speech rate during therapy or data collection, the rates produced by the speakers were “habitual” in the sense that they were simply asked to speak the sentences as they would normally.

If vocal loudness was primarily responsible for changes to formant frequencies and vowel space exhibited by the treatment group, the mechanisms of this change are unclear. Studies thus far report no simple relationship between increased vocal intensity and formant values except for F1, where there appears to be a predictable increase in frequency with increased sound pressure level for a variety of vowels. In the present study, vowel-dependent increases and decreases in F1 and F2 suggest changes in articulatory dynamics which go beyond a wider mouth opening. These findings are consistent with Schulman’s 1989 report of dramatically increased articulatory movement accompanying loud speech [10]. A possible explanation is that intensive practice of high-effort phonation may help trigger or modify centrally stored motor patterns. Preliminary PET scans of reading and phonatory tasks before and after LSVT [11] indicate that significant changes take place in several key motor areas of the brain, including a post-treatment reduction of abnormally high cortical motor and premotor activity and an increase in subcortical (basal ganglia) activation. The authors propose that these changes reflect a
shift from “effortful” to more “automatic” motor-speech behaviors.

5.2. Facial Expression Changes Following Treatment

Overall, it was found that individuals receiving LSVT were more likely to be perceived as more facially expressive on all variables after treatment than before treatment, while members of the RT group showed no such trend. Additionally, scores on the 5-point scale were higher overall for all variables in the LSVT group compared to the RT group, suggesting a greater magnitude of change following voice treatment. Although the changes were mostly non-significant, the LSVT-treated group was consistently considered more expressive. These changes in facial expression suggest that phonation-based treatment may have a clinical impact on expressive output in general. We might speculate that changes in facial mobility and expression are generated from:

* Stimulation of facial nerve through high-effort voice exercises requiring increased facial movement;
* Stimulation of overlapping systems mediating emotional expression (BG/thalamus/anterior cingulate cortex) (figure 4);
* Stimulation of connected voice/face systems through ventral vagal complex [12] including the nucleus ambiguus and the facial and trigeminal nerve nuclei. These nerves, derived from primitive gill arches, control branchiomeric muscles and are involved in the coordination of complex behaviors including swallowing, sucking and facial expression. According to Porges, the ventral vagal complex is “clearly related to [both] the expression and experience of emotion”.

6. CONCLUSIONS

Successful treatment of communication disorders in Parkinson’s disease has been difficult. Recent advances in voice treatment have provided at least one tool – the LSVT – which reportedly works for the majority of people with PD. It appears now that the LSVT may also have additional benefits which go beyond improving voice loudness and quality, including improved articulation and facial expressiveness. While the mechanisms responsible for these changes are unclear, the treatment effects presented here suggest that the LSVT may influence behavior deeply by tapping into centrally stored motor patterns and phylogenetically old neural networks through effortful phonation. Upcoming work will test these hypotheses in greater detail.

7. ACKNOWLEDGMENTS

This work was supported by the National Institutes of Health, grant number R01 DC 05110 and the Beverly Falk Award from the Graduate School of the University of Colorado, Boulder. The authors would also like to thank Dr. Brad Story and Cynthia Fox of the University of Arizona, Tucson for their many contributions to study #1.

8. REFERENCES