To appear in Special Issue, Educational Technology, 2006.

A Virtual Speech Therapist for Individuals with Parkinson Disease

Ron Cole [1], Angela Halpern [2], Lorraine Ramig [2,3],
Sarel van Vuuren[1] Nattawut Ngampatipatpong [1], Jie Yan [4]

[1] Center for Spoken Language Research, University of Colorado Boulder
[2] National Center for Voice and Speech, Denver Colorado
[3] Department of Speech, Language and Hearing Science, University of Colorado Boulder
[4] Department of Computer Science, Bowie State University

Abstract

This article describes a computer program that uses a lifelike animated computer to conduct LSVT speech therapy. LSVT, Lee Silverman Voice Treatment, is an effective speech therapy that teaches individuals with Parkinson disease to think and speak loudly. Over ten years of clinical research have documented pre to post-treatment improvements in the voice and speech of individuals with Parkinson disease, and their post-treatment reports provide evidence of improvements in neural functioning (PET) as well as self confidence and self esteem . While LSVT is effective, there are significant barriers to providing widespread treatment. Barriers to introducing behavioral treatments for neurological disorders include informing and convincing physicians about the value of the treatment, mobility and access limitations of the clients, and developing reimbursement models that assure access to treatment by patients. Computer-based LSVT offers an accessible and affordable alternative to clinician-administered LSVT, that individuals could use in the comfort of their homes. We describe research and development efforts leading to a fully functional LSVT Virtual Therapist system and provide results for the first patient tested.

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Introduction

In the United States alone, over 20 million adults have a neurological disorder that may impair their ability to communicate orally (Yorkston et al., 1988). The prevalence of disordered communication is particularly high in the over six million individuals worldwide diagnosed with Idiopathic Parkinson disease (IPD). At least 89% of these individuals have disordered speech and voice); however, only 3-4% of these individuals receive speech treatment (Hartelius et al., 1994). With IPD predicted to increase significantly as the general population ages, there is a growing need for an accessible, inexpensive, effective treatment for disordered communication for these individuals.

The speech of individuals with IPD is characterized by a raspy or hoarse voice, by monotonic speech, and is produced with insufficient volume. Changes in voice are often one of the first symptoms of Parkinson disease noticed by others, and progressive loss of communication skills by individuals with IPD can be one of the most devastating effects of the disease; as one patient said, *"When you don't talk loud enough, people stop listening."*

Lee Silverman Voice Treatment, LSVT®, focuses on teaching patients to increase their vocal loudness to a normal level and to retrain their sensory system so they use improved loudness in daily living.. Treatment occurs over 16 individual one hour sessions (4 per week) and consists of teaching individuals to produce loud speech without strain or discomfort in a series of voice and speech tasks. The tasks include multiple repetitions of sustained production of the vowel "ah", sustained production of the vowel "ah" while changing pitch, multiple repetitions of functional phrases, reading out loud, and spoken dialog (see Figure 1).

Over a decade of clinical research on LSVT has produced a significant history of published efficacy data (see Fox et al., 2002 for a review) and has generated the first short- and long-term experimental efficacy data for a speech treatment for individuals with Parkinson disease (Ramig et al., 1996; Ramig et al., 2001). These studies have documented that LSVT produces both short-term and long-term improvements in the speech intelligibility and communication abilities of these patients, and their post-treatment reports provide evidence of increased self esteem and self confidence. After LSVT, patients make comments such as: *"My voice is alive again!" "I can talk to my grandchildren on the phone for the first time in years!"* Interestingly, individuals who have undergone LSVT treatment also benefit from additional acoustic, aerodynamic, and physiologic changes associated with treatment, including positive changes in phonation, articulation, swallowing and changes in brain function consistent with improved neural function (Ramig & Dromey, 1996; Smith et al., 1995, Ramig et al., 2001; Dromey et al., 1995; El Sharkawi et al., 2002; Spielman, et al., 2001; Liotti et al., 2003).

Despite the major progress described above, and over 30000 certified LSVT clinicians worldwide, the vast majority of individuals with IPD do not have access to certified LSVT clinicians. For many individuals with IPD, access to treatment is not feasible due to physical disability, geographic barriers or financial reasons; in the U.S. and elsewhere, lack of consistent or comprehensive insurance reimbursement for speech therapy is an obstacle to treatment. Computer-based speech therapy presents a potential solution to this problem by providing access to LSVT through a virtual LSVT speech therapist that interacts with patients, initially in clinics and eventually in their homes, to provide an engaging and efficacious treatment.

Developing an LSVT Virtual Therapist System

The main tasks leading to development of the LSVT VT system prototype included (a) specifying and implementing the "rules of engagement" for controlling the verbal and nonverbal behaviors of the virtual therapist in response to vocalizations produced by the patient; (b) designing the multimedia human computer interface for each of the five LSVT exercises; (c) testing and refining the system through iterative design-and-test cycles; and (d) incorporating the LSVT VT within the treatment sessions for an initial patient with Parkinson disease.

Development of the initial LSVT VT system (tasks a-c) occurred over an eleven month period, and included collaboration between researchers at the Center for Spoken Language Research (CSLR), the National Center for Voice and Speech (NCVS), the Department of Speech, Language and Hearing Science (SLHS) and "LSVT Vets"—individuals with Parkinson disease who had previously completed LSVT. The LSVT Vets worked with the research team to test the developing system and to provide detailed feedback about their experiences and suggestions for improvements. The final task—integration and evaluation of the LSVT VT prototype into LSVT therapy with an actual patient—was conducted at NCVS by an expert LSVT clinician who was not involved in the system development process.

The first step in the development process was to specify and codify the rules that govern clinician responses to patient vocalizations in each LSVT task. For example, in the sustained "ah" task, the clinician's response to the patient depends on the loudness and duration of the patient's vocalization relative to prior vocalizations (if any). Fortunately, these rules were already developed in the context of a previous project that led to the design of an "LSVT Companion," a hand held device that measured and stored data regarding the loudness, duration and pitch of a patient's utterance as it guided them through LSVT exercises. The LSVT Companion also provided auditory as well as visual feedback to the patient using computer graphics presented on the screen of the device (Halpern et al. 2004). We modified these rules as needed for the LSVT VT.

Once the rules had been implemented, significant effort was devoted to (a) designing computer displays that provide accurate and intuitive feedback to the patient about his or her vocalizations, and (b) designing the verbal and nonverbal behaviors of the Virtual Therapist. The Virtual Therapist's behaviors were divided into those that occurred during the patient's speech productions, and those that occurred after the patient's speech productions. In addition, we investigated a variety of novel dynamic displays for providing real time feedback to patients about their vocalizations and also motivating them to achieve specific goals.

<u>Sensory Training "Calibration":</u> One of the greatest challenges of LSVT therapy is sensory calibration, or generalization of loud speech from the clinic to the real world. Individuals with PD believe they are speaking much louder than they are. This problem has been associated with both motor and sensory disorders (Fox et al., 2002). When stimulated to speak louder, patients often complain *"I can't talk like this – it feels too loud"*. The goal of sensory calibration is to enable patients to learn to overcome the mismatch between their perceived vocal effort and loudness of their speech and the actual loudness of their speech. Calibration exercises aim to adjust the patient's sensorimotor perception of vocal loudness and effort so that what initially feels and sounds too loud is now perceived to be within normal limits. As treatment progresses, the increased effort and loudness becomes more automatic. Calibration assessment and exercises are embedded into every treatment session. Calibration assessments are made during informal

conversations with the therapist during sessions. Activities include: helping patients recognize the need for louder speech (i.e., their speech is too soft); convincing patients that their loud speech is within normal limits; and making them comfortable with using louder speech in daily living.

To achieve sensory calibration, the LSVT VT system uses a number of exercises that require continuous speech production, with patients receiving feedback and encouragement for speech produced at targeted loudness levels. Exercises include spoken dialogue interactions with the Virtual Therapist, during which the VT asks open-ended questions in engaging, personalized topics of interest to the patient. The VT also engages the patient in "impromptu" conversations at the end of activities and during "water breaks" (e.g., "How is your voice feeling today?") in order to track progress toward sensory calibration. During a portion of these utterances, the VT provides encouragement ("Use your loud voice") or reinforcement ("That was a great loud voice!").

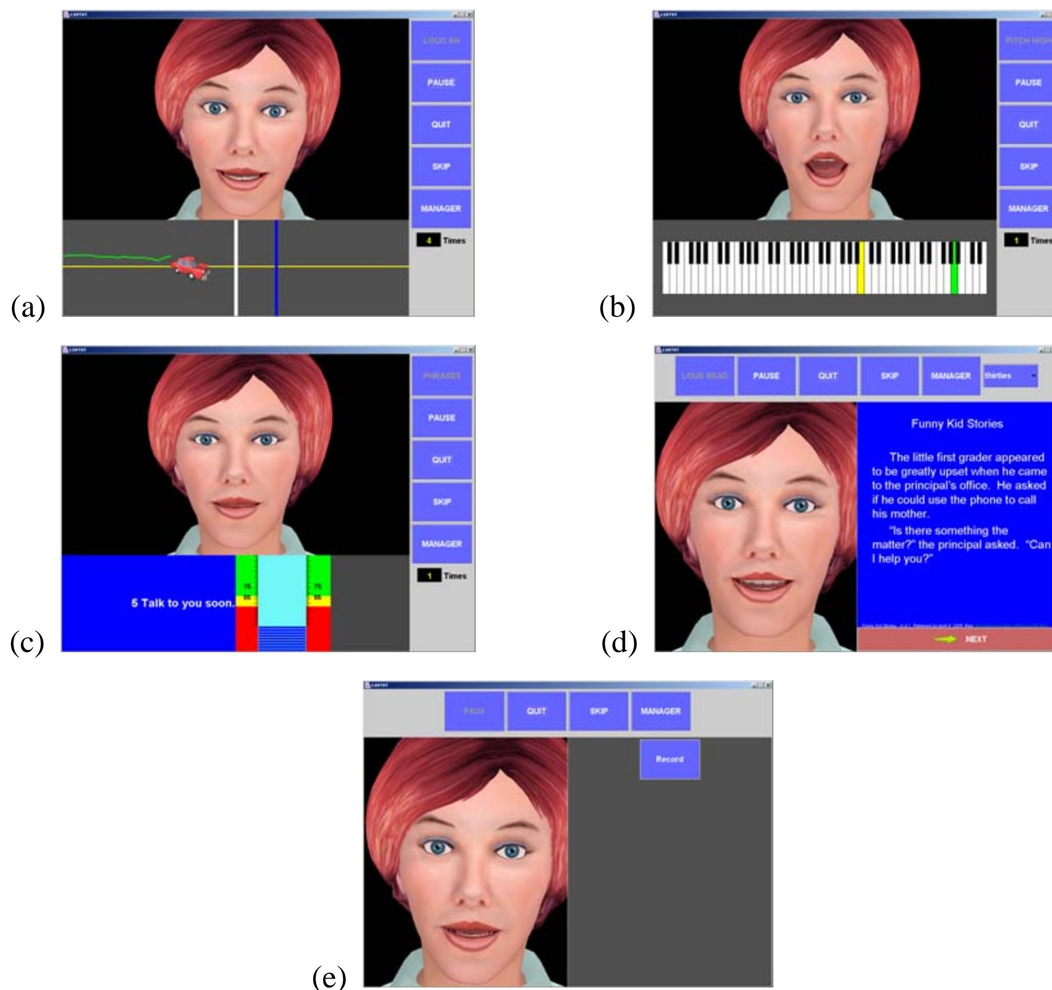

Figure 1. LSVT VT system interface for (a) training sustained loud /ah/ phonation and for (b) training /ah/ phonation with high and low pitch patterns (c) spoken functional phrases, (d) reading out loud (e) spoken dialog interaction.

Figure 1, (a)-(e) show the system interface, respectively, for training (a) sustained loud /ah/, (b) /ah/ with high and low pitch patterns, (c) spoken functional phrases, (d) reading out loud, and (e) spoken dialog interaction. It can be seen that, in addition to verbal and nonverbal feedback from the virtual therapist during and following each utterance, feedback was provided by multimedia displays. For example, in sustained "ah" phonation (figure 1a), the patient's voice causes a car to travel forward if the patient's vocalization meets or exceeds the loudness goal set by the program, indicated by a horizontal line on the display. The car continues to move forward as long as the person maintains this loudness level, and the patient attempts to achieve the goal of moving the car a certain distance as indicated by the vertical lines in the figure. While the patient vocalizes, the VT, "Marni" provides encouragement by smiling and nodding her head and saying phrases such as "go go go". Following the trial, Marni provides feedback to the patient based on their performance, and models desired behaviors. The verbal behaviors, head movements and facial expressions produced by Marni were designed by the research team based on analysis of video tapes of LSVT clinicians during LSVT sessions and based on feedback of the LSVT Vets.

Table 1. Results of User Testing of Initial LSVT VT system.

		Rating					
		1	**2**	**3**	**4**	**5**	
Question	**1 =**	**# of testers rating**					**5 =**
How easy was this to use?	Not easy			1	1	2	Easy
How fun was this to use?	Not fun				2	2	Very Fun
Please rate the appeal of the program	unappealing				1	3	Very appealing
Please rate how engaging you found the virtual therapist to be.	Not engaging		1	2	1		Very engaging
Please rate how much you liked the feedback provided by the virtual therapist.	Not at all			2	1	1	Very Much
Please rate how much the virtual therapist helped you.	She was not helpful				3	1	She was very helpful
Did the virtual therapist make you feel frustrated?	Very frustrated				1	3	Not at all frustrated
Does the computer make it difficult for you to focus on your speech exercises?	Not able to focus				1	3	Very able to focus
How much did you have to think about what the program wanted you to do?	Required constant thought				2	2	Required no thought at all
Please rate how much you liked or disliked the program.	Disliked greatly				1	3	Liked very much
Does the computer help you to focus on your speech exercises?	Does not help				2	2	Is very helpful
How easy is it to interpret the visual display at the bottom of the screen?	Not easy				1	3	Very easy
Is the verbal feedback useful? (e.g. the virtual therapist saying, "good job").	Not useful				4		Very useful
Is the visual feedback at the bottom of the screen useful?	Not useful				2	2	Very useful
Please rate how motivated the program's verbal and visual feedback made you feel.	Very unmotivated				3	1	Very motivated
Were you embarrassed to use this program?	Very embarrassed				1	3	Not at all

Participatory Design with LSVT Vets: Five LSVT Vets (age range 56-83) served as consultants on our project. The LSVT Vets played a key role in participatory design of the LSVT VT system through suggestions and insights that led to significant changes in the system. They were perceptive, and articulate in expressing their opinions, criticisms and suggestions for improving the system and Marni; in almost all cases, these suggestions were incorporated into the LSVT VT program. Following implementation of suggested changes, we administered a survey to 4 of the LSVT Vets after they tested the new system. The results of the survey, summarized in Table 1, reveal that the 4 testers were uniformly positive in their ratings of the system.

First Patient: Next, we incorporated the system into LSVT treatment sessions conducted at NCVS with a 74 year old female patient. This patient was 8 years post diagnosis and presented with mild IPD, characterized by dyskinesias and tremor in her right dominant hand. The patient did not own a computer, and her previous computer experience was limited to two classes that she had taken at a library to learn to use the library computer system.

System Performance and Improvements during Testing: Our first test of the LSVT VT with a patient was designed to provide an initial evaluation of the system, to identify and fix problems, and to gauge system usability and the patient's experiences. The patient was informed that we were introducing a new computer system as part of the therapy and that we expected to discover some problems with the system. The patient understood the situation perfectly, and was tolerant and helpful at all times. Over the course of seven treatment sessions with the LSVT VT, over 20 problems were identified and addressed. During the last LSVT VT session, the system performed well. The patient worked independently with the system the entire session without the therapist in the room.

Quantitative Results: Although system errors occurred, they did not adversely affect the patient's treatment results as indicated by pre-post dB SPL data (see Table 2). These results are consistent with previously published LSVT efficacy data (Ramig et al., 2001).

Table 2. Patient's treatment results as indicated by pre-post dB SPL data.

	Sustained "ah"	**Monologue**	**Reading**
Pre-Treatment	Mean = 76.4	Mean = 67.8	Mean =69.7
Post-Treatment	Mean =86.9	Mean = 78.6	Mean = 81.5

Patient Interview: A ten minute interview was conducted by LSVT researcher Angela Halpern immediately after the last LSVT VT session. One of the most salient features of the interview is the patient's voice—it is loud and clear at all times, without cueing by the interviewer. The patient's responses were informative and very positive, especially considering the problems she encountered while using the system. The patient shared: *"I sense such a difference in my voice and can hear it as well." "I feel a sense of having done something that will continue to be of great benefit." "I feel that I really interact with Marni. Somehow I have a sense of a personality."* We believe her responses bode well for the future of LSVT VT, since the program will improve steadily in the near future.

Lessons Learned: At first glance, development of a virtual LSVT therapist appears straightforward, as LSVT is based on well established principles and well articulated procedures. Yet despite the elegance and apparent simplicity of LSVT, we discovered significant challenges that must be addressed by future research. We learned that expert LSVT clinicians routinely make subtle yet critically important perceptual judgments about the quality of the patient's vocalization, and will occasionally stop the patient from vocalizing if they detect hyperfunction—vocal behaviors that can lead to strain and discomfort. Emulating these complex perceptual judgments and social interactions of LSVT clinicians and their patients is beyond the capabilities of the technologies deployed in our current LSVT VT system. In order to detect hyperfunction and other voice qualities automatically from the acoustic signal, it will be necessary to create a corpus of patients' speech data with utterances labeled to reflect clinician judgments of voice quality. Once this corpus is developed, machines learning techniques can be used to classify utterances, and this information can be used by the virtual therapist to produce appropriate behaviors. Thus, future work is required to provide fully independent patient experiences. In the meantime, LSVT VT can be used to provide an effective component of the LSVT regimen, enabling LSVT clinicians to treat several patients simultaneously.

Acknowledgement: This research was supported by an NIH NIDCD R21 Exploratory Research grant to the University of Colorado, (Ron Cole, PI, Lorraine Ramig, co-PI entitled: "Virtual Therapist Speech Treatment for Parkinson Disease."

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