Motor-Learning-Based Adjustment of Ambulatory Feedback on Vocal Loudness for Patients With Parkinson's Disease

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Summary: Objectives. To investigate how the direct biofeedback on vocal loudness administered with a portable voice accumulator (VoxLog) should be configured, to facilitate an optimal learning outcome for individuals with Parkinson's disease (PD), on the basis of principles of motor learning.

Study Design. Methodologic development in an experimental study.

Methods. The portable voice accumulator VoxLog was worn by 20 participants with PD during habitual speech during semistructured conversations. Six different biofeedback configurations were used, in random order, to study which configuration resulted in a feedback frequency closest to 20% as recommended on the basis of previous studies.

Results. Activation of feedback when the wearer speaks below a threshold level of 3 dB below the speaker's mean voice sound level in habitual speech combined with an activation time of 500 ms resulted in a mean feedback frequency of 21.2%.

Conclusions. Settings regarding threshold and activation time based on the results from this study are recommended to achieve an optimal learning outcome when administering biofeedback on vocal loudness for individuals with PD using portable voice accumulators.

Key Words: Biofeedback–Portable voice accumulators–Motor learning–Parkinson's disease–Voice sound level.

INTRODUCTION

Speech and voice symptoms are common in addition to the general motor symptoms in Parkinson's disease (PD) such as rigidity, tremor, and bradykinesia. Between 70 and 90% of individuals with PD experience speech-related changes.[1,2] Common symptoms include reduced vocal loudness, breathiness, hoarseness, imprecise articulation, monotone pitch, and variations in rate of speech. Cognitive and psychiatric symptoms are also common, including dementia, depression, hallucinations, and disturbed sleep patterns.[3]

Diverse treatment methods are available for patients with PD, including pharmacological, surgical, and behavioral treatments. Pharmacological and surgical treatments generally give good results in terms of reducing motor symptoms such as tremor and rigidity, but the impact on dysarthria is limited and variable. Some studies have shown a positive effect on speech and voice,[4–6] whereas other studies have shown no improvement.[7] Surgical procedures such as deep brain stimulation may even have a negative impact on speech, despite good effect on other motor skills, depending on the locus being stimulated.[8–11] As pharmacological and surgical treatments have proven to have a limited effect on speech and voice symptoms in PD, there is a need for intervention aimed at behavioral modification of speech and voice function. The leading treatment option today is the Lee Silverman Voice Treatment (LSVT LOUD) which has been shown to have a positive outcome with increased vocal loudness lasting for up to 2 years after treatment.[12,13] The goal of LSVT LOUD is to increase the individual's vocal loudness through a high-intensity exercise program consisting of voice tasks such as maximum sustained phonation, production of functional phrases with an increased vocal loudness, and structured speaking exercises aimed at rescaling effort and loudness in different speaking activities. Although positive changes have been shown following intensive voice treatment such as the LSVT LOUD, the carryover of treatment effects to spontaneous speech outside the treatment setting remains a challenge for many patients. This may be attributed to changes in sensory perception in individuals with PD which may lead to an underestimation of the required effort when speaking.[14] In addition, deficits in internal cueing lead to difficulties adjusting vocal loudness in response to implicit cues, whereas external cues can still be used with good effect.[15] One way to help the patients with PD who struggle with the carryover of treatment effects could be to provide direct biofeedback on voice use outside the clinic, by means of a portable voice accumulator.[16]

At the time of writing, three voice accumulators are commercially available: the ambulatory phonation monitor (APM; KayPENTAX, NJ), the VocaLog (Griffin Laboratories, CA), and the VoxLog (Sonvox AB, Umeå, Sweden). These devices differ in design and monitoring features, but all of them enable long-term monitoring of voice sound level (dB SPL) and phonation time (percent time spent phonating during the registration period). The APM and the VoxLog also register phonation frequency (Hz) and the VoxLog registers the level of environmental noise (dB SPL) as well. See Van Stan et al[17] for a review of the features of the devices. In addition to monitoring voice use, the APM and the VoxLog can administer real-time tactile biofeedback regarding voice sound level and phonation

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frequency when applicable. The VocaLog provides feedback capabilities regarding voice sound level only. This sensory biofeedback can be used to remind the wearer of his or her voice use during voice treatment. One example could be to help individuals with PD to maintain an increased vocal loudness throughout the day in everyday speaking situations.

It is common practice today to deliver feedback during voice treatment using verbal cues or by prompting patients to react to auditory or kinesthetic internal cues. Other approaches to enhancing learning during voice treatment have included visual biofeedback,[18–21] combined auditory and visual biofeedback,[22] and tactile biofeedback, which in all cases were given in the form of a vibration in response to voice use.[16,23,24] Reported results have generally been positive.

Recently, there has been an increased interest in how principles of motor learning (PMLs) can be applied to speech motor learning, that is, how structure of practice and feedback facilitates the learning of speech motor skills.[25,26] Research on how different feedback regimes enhance learning is typically done in a strictly defined practice setting and during a restricted period of time. However, using portable voice accumulators, direct feedback on voice use can be provided during long periods of time in uncontrolled settings outside the voice clinic. But, how should the feedback be administered, to provide an optimal learning outcome?

There have been a few studies where some form of biofeedback on voice use has been provided outside the clinical setting. Schneider-Stickler et al[21] used a software program to provide real-time visual biofeedback regarding voice parameters such as phonation frequency, voice sound level, and speech rate to call center agents at their workplace during a 4-week intervention study. There was a significant improvement of vocal performance in the biofeedback group compared with the control group. Schalling et al[16] used the portable voice accumulator VoxLog to provide real-time biofeedback on vocal loudness for individuals with PD. Biofeedback was provided during whole days for 1 week during the subjects' daily activities. Biofeedback in the form of tactile vibration was administered when the subjects spoke with a voice sound level (dB SPL) below an individually predetermined threshold level. A statistically significant increase in voice sound level was observed when the biofeedback was delivered, compared to a 1-week baseline before the intervention. However, the effect trailed off during the week after, when the biofeedback no longer was administered. The authors concluded that further studies need to be made in which practice and feedback are delivered following a structure more tailored to fulfill those PMLs that enhance retention.

Motor learning, as defined by Schmidt and Lee,[27] is a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement. In the motor learning literature, different conditions of practice and types of feedback that enhance learning are specified as the PMLs.[27] When studying learning, it can roughly be divided into two phases; acquisition and retention. Differently structured practice sessions or different feedback regimes can enhance learning differently during these phases. In voice therapy, one of the most important outcome measures is a modified, or learned/relearned, behavior. When evaluating the outcome of such behavioral interventions, it is important to be aware of whether it is the acquisition or the retention that is being assessed. Changes in performance during, or directly after, practice are considered to pertain to the acquisition phase, whereas changes in performance observed hours, days, or preferably weeks or more after practice show retention of the learned behavior. The primary PMLs are summarized in Table 1. The research done on motor learning so far has generally focused on general limb movement. The number of research studies on applying PMLs to speech production to date is limited, but results have been promising.[25,26,28,29]

Most motor learning research has been done on healthy adult individuals. There is reason to believe that, in a neurologically impaired system, the capacity for learning might be affected as well. However, physiotherapy research on individuals with neurologic disorders generally shows transferable results, with the same gains from following the PMLs as healthy

TABLE 1.
Summary of Primary Principles of Motor Learning

Structure of Feedback	Structure of Practice
Knowledge of performance (feedback regarding specific aspects of the outcome)	Massed practice (practice in a small period of time)
Knowledge of results (feedback regarding correctness of the outcome)	*Distributed practice* (practice over a longer period of time)
High-frequency feedback (ie, feedback after every trial)	Blocked practice (different targets in discrete blocks)
Low-frequency feedback (ie, feedback after several attempts)	*Random practice* (different targets are presented randomly)
Immediate feedback (feedback immediately following each trial)	Constant practice (practice in the same context)
Delayed feedback (feedback provided with a delay)	*Varied practice* (practice in different contexts)
	Low number of trials
	High number of trials

Notes: Italicized principles represent those that better facilitate retention of learned motor skills in contrast to improved acquisition with the exception of *high number of trials* which promotes both retention and acquisition.[25,26]