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RESEARCH ARTICLE

NONLINEAR DYNAMIC ANALYSIS OF VOICE IN TEACHERS WITH DYSPHONIA

Mr. Arivudai Nambi Pitchaimuthu, *Dr. Radish Kumar, B., Ketaki Vasant Phadke, Jacqueline B. Fernandes and Dr. Jayashree S. Bhat

Department of Audiology and Speech Language Pathology, Kasturba Medical College, Manipal University, Mangalore-1, Karnataka, India

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ABSTRACT

Nonlinear dynamic analysis identifies and describe the presence of ‘‘rules’’ underlying the seemingly random nature of a severely perturbed voice. Using this technique, the perturbed voice signal may be viewed as ‘‘chaotic’’ in nature rather than randomly perturbed. Nonlinear dynamic analyses of human voices have established the existence of chaos in human voice production. However, very few studies have characterised the voice in teachers with dysphonia using this method. The aim of the present study was to investigate voice characteristics in teachers with dysphonia using Nonlinear Dynamic Analysis methods. 28 teachers and age matched controls in the age range of 20-40 years served as subjects. The voice samples were recorded and a total of 15 Correlation Dimensions were obtained for the two groups. Results showed significant differences in the correlation dimensions between the two groups indicating a complexity in the laryngeal mechanism of teachers. Thus, it was concluded that Non linear dynamic analysis of voice provided a quantifiable data to assess dysphonia in teachers.

INTRODUCTION

The quasi periodic nature of vocal fold vibration is owing to the nonlinearity present in the system. If the laryngeal systems were linear, quasiperiodic vibrations would not happen. However, quasiperiodicity becomes aperiodicity in dysphonic voices with laryngeal pathologies which in turn would lead to increased chaos in vocal fold vibrations. These chaotic vibrations are often analysed using traditional approaches like jitter, shimmer etc. However, these approaches pose several challenges due to the inherent technological limitations. Nonlinear analysis techniques identifies and describe the presence of ‘‘rules’’ underlying the chaotic nature of a severely perturbed voice. Using this approach, dysphonia may be viewed as chaotic system rather than randomly perturbed system. In chaotic systems, the postulation is that an irregular temporal behaviour such as that in dysphonics does not arise fortuitously, but is deterministic in nature where initial condition(s) determines the end result (Williams, 1997). There are two commonly used nonlinear methods to characterize dysphonia which includes phase space portraits and the computation of the correlation dimension (D2). A periodic signal will show a closed trajectory in phase space (like a loop), with increasing perturbation resulting in irregular or chaotic trajectories (a strange attractor) (Herzel, Berry, Titze and Saleh, 1994; Geovanni, Ouaknine, Guelfucci, Yu, Zanaret and Triglia, 1999; Zhang, Jiang, Wallace and Zhou, 2005). The correlation dimension (D2) is a quantitative measure that specifies the number of degrees of freedom (i.e., dimensions) needed to describe a laryngeal system (Zhang, Jiang, Wallace and Zhou, 2005). Jiang, Zhang and Ford (2003) used nonlinear dynamic methods to analyze phonation’s produced via excised larynges. Results showed that measures of D2 helped significantly in differentiating normal versus irregular phonations.

Zhang, Jiang, Biazzo and Jorgenson (2005) compared traditional perturbation and nonlinear dynamic methods to analyze the vowel samples of normal versus subjects with unilateral vocal fold paralysis. Results indicated that both perturbation (jitter and shimmer) and correlation dimension could effectively differentiate normal from dysphonic voice samples. Jitter and shimmer measures were effective only with nearly periodic samples, and correlation dimension was effective with both nearly periodic and severely aperiodic voice samples. Unlike perturbation measures, nonlinear dynamic methods can analyze highly aperiodic signals and does not rely on the identification temporal boundaries (Zhang, McGilligan, Zhou, Vig and Jiang, 2004; Jiang, Zhang and McGilligan, 2006) and are more useful when the speech

****Corresponding author: Dr. Radish Kumar, B.***
Department of Audiology and Speech Language Pathology, Kasturba Medical College, Manipal University ,Mangalore-1, Karnataka, India.

signal is contaminated by breathiness (Zhang, Jiang, Wallace, and Zhou, 2005). Additionally, analysis using nonlinear dynamic parameters permits a shorter signal length in comparison to that required by perturbation measures (Zhang, Jiang, Wallace, and Zhou, 2005), which is beneficial when working with difficult to test population such as pediatrics where sustained phonation is difficult to be elicited.

Over the last few years, nonlinear dynamic analysis have recognized the presence of chaos in human voice production. The traditional measures have not been able to define this chaos by means of l jitter and shimmer measures due to the difficulty in identifying cycle boundaries. However, a nonlinear dynamic method does not depend on cycle boundary identification (Jiang, Zhang, and McGilligan, 2006) but depends on determining the rules underlying the chaos in the voice of patients with dysphonia. The development of phase space portraits and the D2 have been investigated on normals (Balasubramanium, Fernandez, Pitchaimuthu, and Bhat, 2014) and different clinical populations with vocal pathology (Herzel et al., 1994; Jiang et al., 2003; Jiang, Zhang and McGilligan, 2006; Yu Garrel, Nicollas, Ouaknine, and Giovanni, 2007). However, this has not been studied in professional voice users. Professional voice users are vulnerable to develop voice problems than the general population due to the nature of work environment and life style (Stemple, Glaze and Gerdeman, 1995). One such profession that demands use of voice is the teaching profession. Teachers are classified under Level II, to whom even moderate vocal difficulty would prevent adequate job performance (Kaufmann and Isaacson, 1991). In assessment of dysphonia in teachers, studies related to the use of Nonlinear Dynamic analysis are scanty and hence the present study was planned to investigate voice characteristics in teachers with dysphonia using Nonlinear Dynamic Analysis methods.

MATERIALS AND METHODS

Subjects: A total of 56 subjects participated in the study. They were divided into two groups. Group 1 consisted of 28 female teachers in the age range of 20-40 years and group 2 served as the age and gender matched controls. The teachers recruited for the study had teaching experience of more than 5 years, with 4-5 hours of teaching per day. Primary, secondary school teachers were selected for the study. All were diagnosed as having dysphonia based on CAPE-V (ASHA, 2002) by an experienced speech language pathologist. The subjects in the control group were normal healthy individuals and non professional voice users, without any history of vocal abuse/misuse, smoking, neurological and hearing problems.

Instrumentation: Unidirectional microphone connected to HP desktop was used for voice recording. Correlation Dimension was obtained by means of D2.ini.writer based on the TISEAN_2.1 package (Hegger, Kantz and Schreiber, 1999).

Procedure: During the voice sample recording, the subjects were seated in a comfortable chair. The distance between the microphone and the subject's mouth was maintained at approximately 10 cm. All subjects were instructed to phonate vowel /a/ at their comfortable loudness and pitch level for minimum of 3 seconds. These recordings were carried out in a sound treated room in a single setting for all the subjects.

Analysis: The pre recorded voice samples in ".wav" format were fed into MATLAB by means of a "convert" code in order to transform it into ".txt" file format. Once the ".txt" format was obtained, the file was then fed into a D2.ini.writer based on the TISEAN_2.1 package to obtain the Correlation Dimension values. Total of 15 correlation dimension values were obtained for each phonation sample for the two groups individually.

RESULTS

The mean of 15 dimensions of the two groups were tabulated and further averaged to obtain the mean D2 values for each sample. The results of descriptive statistics are as follows.

Groups	Mean	SD
Teachers with dysphonia	6.2	2.93
Normal controls	2.3	1.7

From the above table, it was observed that D2 values were higher in the voices of teachers when compared to normal controls suggesting the presence of excessive chaos in the laryngeal system of teachers. The results of Independent t-test also revealed a significant difference between the scores for teachers (M=6.2, SD=2.93) and controls (M=2.3, SD=1.7) at $p<0.001$ [t (54) =6.11].

DISCUSSION

Teachers use their voice to carry out their job requirements. However, some of these teachers end up having voice problems due to the inappropriate use of their voice. Thus, voice disorders in teachers are thought to be one of the major occupational hazards and are often analysed using perceptual and acoustic measures. The acoustic measures are prone to technological limitations depending on the severity of aperiodicity in the voice signals. Hence, we require an acoustic tool capable of analysing the severely aperiodic voice reliably. In this context, non-linear dynamic analysis was chosen to characterize the dysphonic voices in teachers and normal controls.

The results revealed a significant difference between the two groups for correlation dimension measure. This suggests increased complexity in the laryngeal mechanism of teachers in comparison to normal controls. Increased complexity requires more degrees of freedom to describe a laryngeal behavior. This finding is in consonance with the previous studies that non linear dynamic analysis of voice samples could differentiate dysphonia voices from normal voice samples (Jiang, Zhang and Ford, 2003; Jiang, Biazzo and Jorgenson, 2005). Boominathan, Rajendran, Nagarajan, Seethapathy, and Gnanasekar (1989) reported that 49% of teachers in India have problems such as frequent throat clearing, and loud speaking. These factors play a major role in aggravating voice problems in teachers. These changes would induce irregularity or chaos in the regular oscillations of the vocal folds leading to complex laryngeal systems in teachers.
Life time voice effort, incorrect usage of voice and stress related factors probably would increase the complexity in the laryngeal mechanism. More complex the laryngeal mechanism higher would be the correlation dimension, thus explaining the results of the present study.

Thus, correlation dimension is proven to be a sensitive tool in the diagnosis of voice disorders in teachers. However, other non linear dynamic methods such as use of phase space portraits, lyaponovs component were not carried out in the present study which would add further strength to the use of nonlinear dynamic methods in the voice analysis.

CONCLUSIONS

The present study characterized dysphonia in teachers using Nonlinear Dynamic Analysis. The results showed significant differences in the mean D2 values between teachers and the control group indicating that teachers had higher correlation dimension than the control group. This explains the presence of increased complexity in the laryngeal mechanism thereby providing chaos during vocal fold vibration. Thus non linear dynamic analysis of voice provided a quantifiable data to assess dysphonia in teachers. Further studies may address other non linear dynamic analysis parameters in teachers.

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