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Research article

NONLINEAR DYNAMIC ANALYSIS OF VOICE: A NORMATIVE STUDY IN THE INDIAN POPULATION

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ABSTRACT

Background: The aim of this study was to establish normative data for the Indian population using Nonlinear dynamic analysis. In this study, correlation dimension, a measure of nonlinear dynamic analysis was performed for normophonic young, middle aged and elderly voices. **Materials and Methods:** For this purpose, normophonic young, middle aged and elderly individuals were selected without a history of voice/respiratory problems and vocal abuse/ misuse. 60 participants were selected in each group. All of these individuals had a normal voice as evaluated through GRBAS scale. Sound Recorder, on a computer desktop was used for voice recording and "convert" code in MATLAB as well as D2.ini.writer software based on TISEAN package (Hegger, Kantz & Schreiber, 1999) was used for the calculation of Correlation dimension (D2). Correlation dimension measures were obtained for each participant, for both steady vowel phonations (/a/, /i/, /u/) as well as narration samples. **Results:** The correlation dimension measures across the group revealed a significant main effect of the groups indicating correlation dimension increases with increase in age. **Conclusions:** The application of nonlinear dynamic measures in the assessment of voice is a novel venture and thus this study provides normative data for correlation dimensions in the Indian population for future comparisons against the disordered voice samples. Further studies are warranted to investigate the same in the clinical population. Also other nonlinear dynamic analysis methods need to be investigated to obtain the normative data in the Indian population.

Keywords: Nonlinear dynamic analysis, Correlation dimension, Normophonic voice,

INTRODUCTION

Acoustic analysis does not appraise completely the true nature of the underlying vocal fold function. Yet, acoustic analysis is still used in the voice assessment due to some level of correspondence between voice production and voice acoustics. Though not perfect, much can be inferred about the vocal physiology based on the acoustic analysis. A normal voice signal is said to be quasi periodic and must have very minimal cycle to cycle variability in frequency as well as amplitude. When the voice is periodic and/or nearly periodic, measures such as Jitter and Shimmer are reliable whereas they are unreliable in the case of severely perturbed voices due to the difficulty in identifying cycle boundaries. Due to this reason, traditional measures such as jitter, shimmer have lost their value in the assessment of aperiodic voices.

Nonlinear dynamic analysis endeavor to recognize and explain the presence of ''rules'' underlying the random nature of a severely perturbed voices. This approach considers the severely perturbed voices as

''chaotic'' in nature. Chaos theory believes that erratic looking temporal behavior does not arise randomly, but is deterministic in nature i.e., initial condition(s) determines the end result based on some law/rule.[1] A potential advantage of this method, when compared with traditional perturbation measures of the voice signal, is the possibility of objectively quantifying dysphonia severity without the requirement of cycle boundary detection. Also, non linear methods have the capability of analyzing all the types of voice signal (periodic as well as aperiodic voice). There are two most commonly used nonlinear methods which include phase space portraits and the subsequent computation of correlation dimension.[2]

Usually, voice waveform data are entrenched in phase space and then reconstructed using the method of lag variables or delay coordinates.[3] A periodic signal will show a closed trajectory in phase space, with increasing perturbation resulting in irregular or chaotic trajectories.[3-5] Though vocal fold vibration is graphically represented as a trajectory in phase space with time,[2] further computation is required to objectively quantify the complexity of the signal in space.

Correlation dimension (D2) is one such measure that quantifies the complexity of the signal by specifying the number of degrees of freedom (ie, dimensions) needed to describe a dynamic system like voice.[5] If the dynamics of a system can be determined to be low dimensional, then a complex determinism may exist, which is responsible for the observed signal profile.[6] Alternatively, more complex the system, greater the number of degrees of freedom are required to describe its dynamic state, and the higher the correlation dimension. These nonlinear dynamic methods have been analyzed in both pathological and non pathological voice samples[5, 7-9] in several studies. In the modern clinical outlook, its popularity is limited. Also, there are no normative available in the Indian context. Hence, the present study is an attempt in this direction. Results of this study would guide the speech language pathologist in a more efficient assessment and management of voice disorders.

Aim of the study: To obtain a normative data for voice using Non Linear Dynamic Analysis.

METHOD

This study followed a cross sectional normative study design, with Non Random Convenient Sampling. The institutional ethical approval was obtained prior to the conduct of the study. Participants were alienated into three different groups based on age[10] which are as follows:

Table 1: Age Range Classification[10]

AGE RANGE	GROUP NAME
18 – 40 Years	Young Adults
41- 60 Years	Middle Aged Adults
61 Years & Above	Older Adults

Each group consisted of 60 individuals out of which 30 were females and 30 were males. All the participants were normal healthy individuals without any history of vocal abuse/misuse, smoking, neurological, organic and non organic vocal pathological conditions. All the participants had a normal voice as evaluated perceptually by three trained speech pathologists using the GRBAS (Grade Roughness Breathiness Asthenia Strain) scale.[11] Prior to the study an informed consent was obtained from all the participants.

Instrumentation: Sound Recorder, a computer device was used for recording of the voices. A dynamic microphone was used to record voice. Adobe Audition (version 3.0) was used for noise reduction from the samples. Correlation Dimension was obtained by means of MATLAB (matrix laboratory) developed by Math Works and D2.ini.writer software based on TISEAN package.[12]

Procedure:

During the voice sample recording, the participants were seated in a comfortable chair. All the voice samples were directly recorded in Sound Recorder using a dynamic microphone. The distance between the microphone and the participant's mouth was constantly maintained at 10 cm. After a brief period of familiarization, the participants were instructed to phonate vowel /a/ at their habitual loudness and pitch as if the vowel was a word in a conversation, and were also instructed to avoid singing it. The task was demonstrated to each participant and instructions were repeated as and when required. The task was repeated if the experimenter felt that the voice produced did not sound like their habitual voice production. The recordings were carried out in a

sound treated room in a single sitting for all the participants. Similarly, a narration sample was also recorded using the same set up. A common topic that was maintained for narration was “home”.

Analysis: The pre recorded voice samples collected for each participant was individually analyzed by means of a code written using MATLAB. The recorded voice samples were stored in “.wav” format. The voice samples were then 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 package[12] in order to obtain the embedding dimension values. (Correlation Dimension, D2). A total of 15 correlation dimension values were obtained for each sample. The mean values for every dimension were calculated in order to obtain a normative range across the three age groups as well as to compare the variation amongst the three age ranges.

RESULTS

The present study was carried out with an aim to obtain normative data for the acoustic analysis of voice using Non Linear Dynamic Analysis. Age related differences were analyzed using one way ANOVA with bonferronis post hoc test.

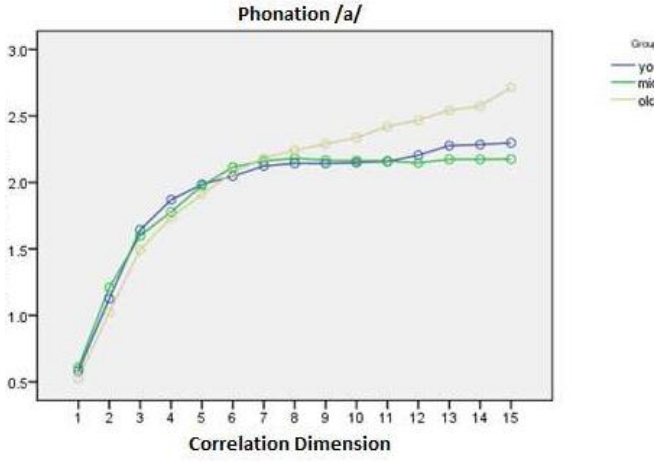

Fig. 1: Mean dimension values for sustained vowel /across the three groups.

The above figure depicts no significant change amongst the three groups until the 7th dimension at p>o.05. However, a gradual increase in the mean dimension values was observed in older adults beyond the 8th dimension at p<0.05. Young and middle aged adults displayed similar profiles in the mean correlation dimension values.

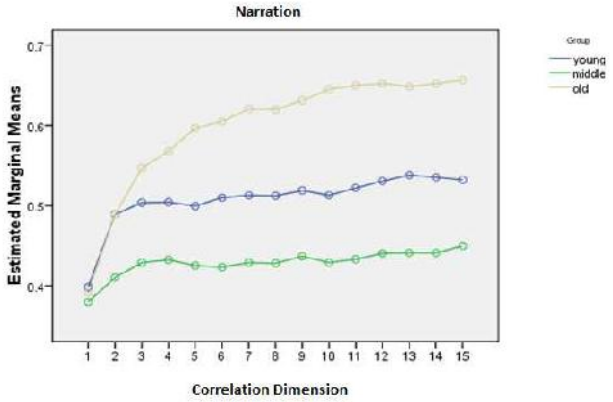

Fig. 2: Mean dimension values for narration across the three groups.

The above figure indicates differences in the correlation dimension values across the three groups. Older adults showed a higher dimension value in comparison to young adults at p<0.05. The middle aged adults depicted a comparatively reduced mean value when compared with younger and older adults at p<0.05.

The results revealed significant differences for phonation of vowel /a/, and narration at p < 0.05.

DISCUSSION

With the development of nonlinear vocal fold models, studies have put forward the means of assessing nonlinearity in the voice signal through various methods. These methods provide quantifiable data by considering the chaotic components in a voice signal. Various nonlinear dynamic analysis methods have been described in the literature. These include the development of phase space portraits, attractors, and the use of correlation dimension, all of which have produced variable results. In the present study, correlation dimension was used to characterize the normal voice samples across adults and geriatric in Indian population. Results of one way ANOVA revealed that the correlation dimension measures across the group revealed a significant main effect of the groups i.e., as the age increases, correlation dimension values increases. This suggests that as the age increases, complexity in the laryngeal mechanism also increases thereby providing chaos in the vocal fold vibration.

Sulica reported that the age related anatomical changes occurs in the laryngeal system such as degenerative changes to the lamina propria and the

mucosal glands in the larynx, all of which results in reduced production of laryngeal mucus which further causes intermittent alteration in vocal fold vibratory patterns thereby inducing changes in pitch, loudness and quality as well.[13] Thus, it can be stated that non linearity is inherent in the laryngeal mechanism with the presence of chaos in the voice production.

Higher correlation dimension values were reported in systems that have more chaos or deterministic noise. They suggest that the anatomical alterations in the vocal mechanism that occur for any pathological conditions result in higher values of correlation dimension. Hence, we can opine that anatomical alterations in the vocal mechanism that are exhibited by aged individuals could be the underlying cause for obtaining higher correlation dimension measures in this study.[14] Baken reported that the Fractal dimension values are representative of the vibratory function of the vocal folds.[15] Baken considered vocal folds to be oscillators whose movements if affected by means of any change in the vocal mechanism be it due to aging or organic pathology results in irregularity or chaos in the regular oscillations of the vocal folds. This irregularity in oscillation caused an increase in the value of the fractal dimension.[15]

Alternatively, a study carried out by Nicollas et al[16] in children aged 6-12 years using nonlinear dynamic analysis reported that correlation dimension measure decreased with increasing age in children. Their results were attributed to several factors. The main factor considered amongst them was the evolution of the pediatric larynx.[14,17] In support of this view, Eckel et al[17] reported that the subglottic airway rapidly increases during the first 2 years and then follows a linear mode. During the same period, fundamental frequency decreases from 450 to 300 Hz, while membranous vocal fold increase by 1 mm. Histologically, it is well known that the collagen distribution in the vocal folds varies with age, with large variations in collagen fiber type occurring during the period between 6 years and mutation, corresponding to the ‘‘pre mutation’’.[18] These histological changes, though not measured in the present study would have contributed to increased correlation dimension values in the older adults. However, it is interesting to note that correlation dimension values were more for young adults in comparison to middle aged adults. The explanation for this was unclear.

Thus, nonlinear dynamic analysis of voice provided a quantifiable data on the age related changes in the voice production. It was evident that as the age increases, complexity of dimensions also increases with the decreased predictability of geriatric voices. This effect was pronounced in both phonation as well as the narration samples. Thus, it can be considered as a useful tool in the assessment of voice. However, it cannot replace the existing voice analysis techniques available to the voice clinician. Yet, it may add to the battery of voice assessment procedures.

CONCLUSION

The application of nonlinear dynamic measures in the assessment of voice is a novel venture and thus, this study provides normative data for correlation dimension in the Indian population for future comparisons with disordered voice samples. The correlation dimension measures across the group revealed a significant main effect of the group indicating that, correlation dimension values increases with increase in age. Further studies are warranted to investigate the same in the clinical population. Moreover, another nonlinear dynamic analysis methods need to be investigated to obtain the normative data in the Indian population.

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