ACOUSTIC VOICE QUALITY INDEX (AVQI) AND PERCEPTUAL MEASURES IN INDIAN POPULATION

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ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI,

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MAY 2017

CERTIFICATE

This is to certify that this dissertation entitled ***"Acoustic Voice Quality Index (AVQI) and perceptual measures in Indian population"*** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 15SLP014. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
May, 2017

Dr. S. R. Savithri
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CERTIFICATE

This is to certify that this dissertation entitled ***"Acoustic Voice Quality Index (AVQI) and perceptual measures in Indian population"*** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student (Registration Number: 15SLP014). This has been carried out under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled ***"Acoustic Voice Quality Index (AVQI) and perceptual measures in Indian population"*** is the result of my own study under the guidance of Dr. T. Jayakumar, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, **Registration No. 15SLP014**

May, 2017

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Voice is a very important aspect of human communication. It serves as a medium through with speech is expressed. It is through voice, that music is produced and emotions are reflected. The personality of an individual is mirrored in his/her own voice. A blend of several physiologic activities such as respiration, phonation, and resonance subsequently gives rise to human voice. An individual is regarded to have dysphonia when his/her quality, pitch, or loudness is found to be markedly deviated when compared to that of other people of similar age, gender , geographical region, and endemic background (Coyle, Weinrich & Stemple, 2001). The human voice, being multidimensional in nature, when affected, can give rise to a variety of disorders (Hakkesteegt, 2009).

The primary task of a speech language pathologist (SLP) who deals with a person having dysphonia is to carry out an assessment and to make an appropriate diagnosis to aid in successful management. The quality of human voice can be evaluated qualitatively by the listening ear of the clinician and also quantitatively through the usage of instruments (Hakkesteegt, 2009). The European Laryngeal Society (ELS), recommends the usage of a test battery for the assessment of voice disorders. ELS recommends that the assessment of voice disorders should consist of laryngostroboscopy, perceptual voice assessment, acoustic analysis, aerodynamic measurements as well as subjective self- evaluation of voice (Dejonckere *et al.*, 2001). However, in a clinical setup, it may be difficult that all the clinicians have access to the variety of assessment tools mentioned above. Thus, the evaluation of voice disorders frequently involves combinations of perceptual as well as acoustic measurements.

One major advantage of perceptual evaluation of voice is that it is a means of assessment that is easily available to most of the practicing speech language pathologists and laryngologists for daily use in their clinical setups. Some of the measures that are widely used for perceptual evaluation of voice quality include, the Darley Rating System (Darley, Aronson & Brown, 1969), the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scales (Hirano, 1981), Buffalo Voice Screening Profile (Wilson, 1987), and the Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) Scales (Kempster, Gerratt, Verdolini, Barkmeier-Kraemer & Hillman, 2009). All of these scales have been validated for several populations across the globe through a number of studies and are being frequently used by voice clinicians (Nemr *et al*., 2012). Although perceptual evaluation of voice is regarded as gold standard while assessing a person with dysphonia, it is vulnerable to a lot of variations which arise due to several listener, subject or task factors.

Acoustic measurements of voice on the other hand, have been used in the assessment of voice due to their advantages such as non-invasiveness and affluence of use. Acoustic measurements, quantifies the degree of severity of dysphonia; which when carefully interpreted can become a useful measure to scale dysphonic severity, and to monitor improvements in voice quality with medical or therapeutic management. Acoustic measures have been regarded as the utmost reliable objective measure of voice quality. (Carding, Wilson, MacKenzie, & Deary, 2009).

For objective evaluation of the voice quality, several acoustic measures that include frequency related measures (e.g., fundamental frequency, habitual Frequency, frequency range etc.) amplitude related measures (e.g., habitual intensity, extent and fluctuation of intensity etc.), perturbation related measures (e.g., jitter, shimmer, etc.) as well as harmonics related measures (e.g., harmonics to noise ratio etc.) have been widely used by various researchers (Dejonckere & Lebacq, 1996; Hirano *et al*., 1988; Rabinov *et al.*, 1995; Picirillo *et al.*, 1998; Wolfe, Fitch & Cornell, 1995). However, the usage of several individual acoustic parameters did not seem to truly reflect the effects of the disorder on the multiple dimensions of voice. Also most of these single acoustic parameters were found to have limited validity. (Awan & Roy, 2006). Thus, several researchers have tried to devise a multiparametric protocol to investigate the voice quality, to differentiate between various categories of voice and degrees of dysphonia severity (e.g., Awan & Roy, 2006; Ma & Yiu, 2006; Wuyts *et al.*, 2000; Yu, Ouaknine, Revis, & Giovanni, 2001). However, from the plethora of acoustic measures that are available, the efforts to converge into a solitary measure which would consistently point to the existence and severity of dysphonia, was held up by issues relating to the test-retest reliability and validity, as well as several other confounding factors (Carding, Wilson, MacKenzie, & Deary, 2009). But, several researchers have stated that, the use of multiparametric measurements which combine several objective parameters are better to assess the voice quality than with the use of single parameter measurements (Michaelis, Frohlich & Strube, 1998; Klein, Piccirillo & Painter, 2000; Yu, Ouaknine, Ravis & Giovanni, 2001; Yu, Revis, Wuyts, Zanaret & Giovanni, 2002; Hartl, Hans, Vaissiere & Brasnu, 2003).

Although there have been various parameters used for documenting the voice quality objectively, the Dysphonia Severity Index (DSI) (Wuyts *et al.* 2000) is a multiparametric measurement which has been reported to be a robust measure and been used consistently as an outcome measure in various studies (Timmermans, De Bodt, Wuyts, & Heyning, 2004). DSI considers highest frequency, lowest intensity, Maximum Phonation Time (MPT) as well as jitter to arrive at a numerical value that reflects the voice quality of a given individual. In a study by Hakkesteegt, Brocaar, Wieringa, & Feenstra (2008) it was revealed that the mean DSI scores across subject groups can be highly stable and that it correlated well with the perceptual measures that are available. In the Indian context, Jayakumar & Savithri (2012) developed the normative for DSI and compared it with the European norms. Evident differences were found between the Indian and European population in terms of Highest F_0, MPT as well as the DSI values. Neelanjana & Jayakumar (2011), compared DSI scores with that of CAPE-V in individuals with voice disorders. It was revealed that a significant correlation exists between DSI and most of the parameters of CAPE-V.

DSI takes into account vocal range which is a parameter, in the true sense, which can be difficult to obtain. It can vary widely over several trials and requires more time and effort. Studies have shown that it takes almost 20 minutes to half an hour to obtain a satisfactory Voice Range Profile (Pabon, 1991; Titze *et al*., 1995). Several researchers have suggested that various procedural variations in obtaining vocal frequency and intensity limits can lead to high inter and intra subject variability (Gramming, Sundberg, & Åkerlund, 1991; Ma *et al.* 2007). Also the Lowest Intensity that is considered for DSI requires high standard instrumentation that gives precise intensity measurement. A high quality Sound Level Meter (SLM) or such apparatus have been recommended for use to obtain this parameter. But it might not be feasible with majority of commercially available voice diagnostic instruments. Even though sustained vowels show a lessened variation within the speech signal due to prosodic and voicing factors and permit ease of standardization of the sample, continuous speech is a more usual speaking behaviour, and is the environment in which perceptual decisions regarding the appropriateness of quality of voice are made (Carding, Carlson, Epstein, Mathieson, & Shewell, 2000). However, given the fact that acoustic qualities of sustained phonation, as well as connected speech varies, including a connected speech sample can serve the function of increasing the ecological validity of the analysis. (Wolfe, Cornell & Fitch, 1995; Zraick, Wendel & Smith-Olinde, 2005). Thus arises a necessity to incorporate even connected speech sample within the acoustical analysis so that the sample used to diagnose will be more similar to that of the individual's habitual speaking voice (Reynolds *et al.*, 2012).

One recently introduced technique to measure the severity of overall dysphonia involving sustained phonation as well as connected speech is the Acoustic Voice Quality Index (AVQI) (Maryn *et al.*, 2010). They made use of concatenated samples of sustained vowel as well as connected speech which were subjected to analysis of 13 acoustic measures (based on fundamental frequency perturbation, amplitude perturbation, spectral and cepstral analyses). Following this, stepwise multiple linear regression analysis was applied and a six-variable acoustic model for the multiparametric measurement of overall voice quality of the concatenated samples was derived.

The parameters used for AVQI are, smoothed cepstral peak prominence (CPPS), harmonics-to-noise ratio (HNR), shimmer local (SL), shimmer local dB (ShdB), slope of the long-term average spectrum (slope) and tilt of the trendline through the long-term average spectrum (tilt). Thus AVQI is constructed as AVQI = 2.571*(3.295-0.111*CPPS - 0.073*HNR - 0.213*SL + 2.789*ShdB - 0.032*Slope + 0.077*Tilt) (Maryn *et al.*, 2010). A score of 2.95 or below obtained on AVQI identified the sample to be normophonic for Dutch speakers (Maryn *et al.*, 2010).

It was found that a positive association exists across AVQI and perceptual dimension of overall dysphonia, and therefore, the higher the AVQI score is, more affected will be the overall voice quality and vice versa. The correlation across AVQI and the perceptual dimension of overall dysphonia was found to be 0.78, which demonstrates a high concurrent validity (Maryn *et al.*, 2010). Also, AVQI was found to be sensitive to changes owing to treatment, validating its role as a robust objective voice treatment outcomes measure also (Maryn, De Bodt, & Roy, 2010). AVQI was identified as stable across different phonetic and linguistic structures across several languages such as English, Dutch, French, German, Japanese, Korean, Lithuanian etc. even though it involves continuous speech as one of the measures that contributes to it (Maryn *et al*. 2010a, 2010b, 2014; Reynolds *et al.*, 2012; Barsties & Maryn, 2012, Hosokawa *et al.*, 2017). Also, recent studies revealed a strong correlation of AVQI with the GRBAS scores as well as that of CAPE-V for Korean (Maryn, Kim, & Kim, 2016) as well as for Lithuanian (Uloza *et al.*, 2017) languages.

In a study by Reynolds *et al.*, (2012) it was revealed that AVQI has high diagnostic accuracy concerning its applicability to the paediatric voice. They found that, AVQI correlates with GRBAS scale and that AVQI is an appropriate measure for evaluation and diagnosis of dysphonia in children.

Similarly, AVQI has been used to document the effects of voice therapy on voice quality in in a variety of population including children (Reynolds, Meldrum, Simmer, Vijayasekaran & French, 2016), and adults with several voice disorders (Hosokawa *et al.*, 2017, Uloza *et al.*, 2017).

In a recent study by D'haeseleer, Meerschman, Claeys, Leyns, Daelman, & Van Lierde, (2016), an attempt was made to profile the voice of theatre artists using AVQI. Thus, in the present scenario of voice sciences, AVQI demonstrates an incipient role as a promising voice measurement tool.

Need of the study

AVQI was developed by Maryn *et al.*, (2010) for European normal participants and dysphonic subjects. In the due course it is emerging as a potential voice measurement tool that can be used to evaluate the voice quality and monitor changes due to therapeutic management as well. However, there is a dearth of studies in the Indian context using AVQI with normophonic as well as dysphonic subjects. Therefore, there is a need to evaluate AVQI on normophonic as well as dysphonic Indian population and to develop reference data to compare with European reference.

According to Jayakumar & Savithri (2009) evident differences exist between the Indian and European population in terms of DSI values and some of its constituents *viz.*, Highest F_0 and MPT values. There is a possibility that such a difference may be present even for AVQI. Also it needs to be verified with perceptual evaluation like GRBAS. Hence, the current study attempts to provide an understanding towards the measure of AVQI on normophonic as well as dysphonic subjects in the Indian context and to correlate these with the findings of perceptual evaluation using GRBAS.

Aim of the study

The aim of this study is to develop reference data for AVQI and to validate AVQI with the perceptual measures obtained for individuals with normal voice quality and to that of individuals with dysphonia within the Indian context.

Objectives of the study

- To determine the AVQI scores for individuals with normal voice quality in the Indian population.
- To determine the AVQI scores for individuals with dysphonia in the Indian population.

- To determine the correlation of objective evaluation (AVQI) with that of perceptual evaluation (GRBAS) for individuals with normal voice as well as individuals with dysphonia.

CHAPTER 2

REVIEW OF LITERATURE

"The human voice is extraordinary. It is adept of passing on not just the complex thoughts, but also elusive emotions. Within an instant, it can convey the terror of a scream or the beauty of a song." This is the beauty of human voice as explained by Sataloff (2005). The human voice, is a principal medium to carry out the vocal communication and aids in conveying the emotions to the listener. It is of very much importance when it comes to day to day communication although it often goes unnoticed. A normal human voice is judged by its quality, pitch and loudness. In other words, the human voice is multidimensional in itself.

The human larynx and voice like any other human organ and its function can be affected by several anatomical lesions or physiological malfunctioning. It can also be affected due to several psychological causes. A variety of disorders can arise when the human voice if affected owing to its multidimensional nature (Hakkesteegt, 2009).

A Speech Language Pathologist (SLP) along with an otolaryngologist are the professionals involved in the assessment of the voice and its disorders. While the SLP evaluates the functioning of the phonatory system, the otolaryngologist is primarily involved in evaluating the anatomical structures of the phonatory system. The assessment of the disordered voice or dysphonia is essential for a variety of reasons such as to arrive at a diagnosis of the problem; to probe at the possible etiology of the problem; to plan appropriate management strategies (medical or behavioural); and to monitor the outcome of the management strategy used.

Several assessment protocols have been recommended by several organizations in order to carry out an assessment of the dysphonic voice. One among them is the assessment protocol recommended by the European Laryngeal Society. According to the European Laryngeal Society, an evaluation of voice disorders should involve laryngostroboscopy, perceptual voice assessment, acoustic analysis, aerodynamic measurements as well as subjective self- evaluation of voice (Dejonckere *et al.*, 2001).

However, it is not possible to have a combination of all these measures in each and every clinical setup in the present scenario owing the financial considerations. The quality of human voice can be evaluated qualitatively by the listening ear of the clinician and also quantitatively by the usage of instruments (Hakkesteegt, 2009). In assessing the human voice, these two methods have been identified as easier to perform, less cumbersome, competent and cost effective as well. Therefore, the practicing clinicians often tend to choose the perceptual as well as the acoustic analysis of voice along with the visual examination of the larynx by an otolaryngologist for the assessment. Within perceptual evaluation and acoustic measurements, there are several measures that are accessible to the clinicians to aid in diagnosing as well as managing persons with voice disorders.

Perceptual Evaluation of Voice

Perceptual evaluation of voice is mainly describing "how the voice sounds like". It is very often focussed on making use of the trained ear of the SLP to judge on the quality of the voice. However, it can be influenced by several factors which are primarily dependent on the listener. Some of these factors include the experience of the listener, the distinctive standard used to equate the perceived voice quality, etc. (De Bodt, Wuyts, Heyning, & Choux, 1997). This distinctive standard used by the listener is somewhat based on the extent of severity of voice problem which the clinician uses to critic. Also there can be lack of consensus on the terminology and the definitions used and it can also lead to lack of agreement among the listeners regarding the quality of the voice judged.

In order to diminish these limitations and to improve the consensus among the listeners various perceptual rating scales have been formed to emphasize on and to enunciate specific facets of the quality of voice. There is a plethora of perceptual evaluation measures that are available which make use of Equal appearing Interval scale, Likert scale, Visual Analog Scale etc. to judge the quality of voice. According to Carding, Carlson, Epstein, Mathieson, & Shewell (2000), almost 57 scales were being used in America and Britain to assess several voice disorders. From the huge literature which has been devised about the reliability of several perceptual evaluation scales, four most common scales reported on in the literature are the Vocal Profile Analysis (VPA) (Laver, 1991); Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scales (lsshiki, Okamura, Tanabe, Morimoto, 1969; Hirano, 1981); Buffalo Voice Screening Profile (Wilson, 1987); and the Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) Scales (Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman, 2009).

Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scales

The `GRBAS Scale' was introduced by Hirano, (1981). It was devised in an effort to elucidate the psychoacoustic phenomenon of hoarseness making use of the Osgood’s Semantic Differential Technique (1964) (as cited in Hirano, 1981). This was developed further by Isshiki and the Japanese Society of Logopedics and Phoniatrics which resulted in the GRBAS scale. This scale evaluated five aspects of vocal quality which are as follows:

G (Grade): "Degree of abnormality”

R (Roughness): "Irregularity of the vocal cord vibration"

B (Breathy): "Air escape through the glottis"

A (Asthenia): "Absence of Power/Presence of weakness"

S (Strained): "Hyper Functional State" (Hirano, 1981).

For each aspect addressed, a four-point scale is used to address the severity ranging from zero to three which is given to the clinician to make a decision about the severity of each aspect (De Bodt, Wuyts, Heyning, & Choux, 1997). In GRBAS, 'zero' equals normal, with 'one' being mild, 'two' being moderate and 'three' being severe. Of those scales mentioned above the 'GRBAS' scale introduced by Hirano (1981) is the one which is most widely used.

Kreiman, Gerratt, Kempster, Erman, & Berke (1993) reviewed 57 research articles selected from the literature that employed several approaches to the perceptual evaluation of voice. Among these, the GRBAS scale was found to be widely used for describing the disordered voice quality (Carding, Wilson, MacKenzie, & Deary, 2009). Also GRBAS was found to be a faster scale in assessing the voice problem than compared to CAPE-V by Nemr *et al.*, (2012).

Webb, Carding, Dewy, MacKenzie, Steen & Wilson, (2004) carried out a study to determine the reliability of 3 common scales (The Buffalo Voice Profile, The Vocal Profile Analysis Scheme (VPA) and GRBAS). Sixty-five distinctly dysphonic and 5 normal voices were rated by seven experienced and trained speech-language pathologists on three scales. Within the Buffalo Voice Profile, only the overall grade proved to be reliable. The VPA scheme had a poor to fair (κ ranging from 0.00–0.29) reliability. Thus, the reliability of VPA was compromised despite its advantages of being multi-dimensional and in-depth evaluation of voice types. The GRBAS was reliable for all of its constituents except for the Strain parameter which was moderate between raters (κ = 0.48). The thorough reliability analysis by these authors contrasting the efficiency of three commonly used rating scales provided additional proof to upkeep GRBAS as a modest reliable tool for clinical use.

De Bodt, Wuyts, Van De Heyning & Croux, (1997) used GRBAS scale to find out the effect of experience and professional background on the perceptual evaluation of voice samples. For this, 9 voice samples were presented to a group of twenty three judges twice which included both otolaryngologists with and without experience along with speech pathologists. Results indicated that the test re-test reliability was moderate using GRBAS scale (κ = 0.60) and the best agreement was obtained for the G (grade) parameter and the poorest agreement was for the S (Strained) parameter. It was concluded that professional background had a larger influence on perceptual evaluation compared to experience.

Despite its several advantages, the limitations of the GRBAS scales were that it just rates parameters at laryngeal level only and no supra-glottic parameters are rated. Also it excludes the rating for frequently used parameters such as pitch and loudness.

The Vocal Profile Analysis (VPA) Scheme

Vocal Profile Analysis (VPA) scheme was developed by a phonetician and a Speech-Language Pathologist (Laver, 1991). The VPA is a descriptive scheme which lets a trained listener to define as well as evaluate the quality of voice in a conversational task or a reading task. The whole imprint of voice quality is made from a series of possibly independent constituents or manipulations at both laryngeal and supra - laryngeal levels and also within the suprasegmental aspects of the vocal function. Each characteristic of voice is contrasted with an explicitly demarcated "natural" baseline and a rating figure is provided for each characteristic.

The limitations of VPA Scheme are that consistent listening skills practice is needed and that it is more time consuming compared to other frequently used perceptual scales.

BUFFALO Voice Screening Profile

The Buffalo voice screening profile (Wilson, 1987) was generated for the explicit assessment of voice of paediatric subjects. The buffalo voice screening profile makes use of an equal-appearing interval scale of five points, with l being "normal" and 5 being "very severe" deviancy from the normal voice quality. Analysis of twelve major aspects of voice production such as Laryngeal tone, Pitch, Loudness, Nasal resonance, Oral resonance, Breath supply, Muscles, Voice abuse, Rate, Speech anxiety, Speech intelligibility, Overall voice rating is carried out using this profile. It targets to define both vocal features as well as more general characteristics of vocal behaviour.

Though it uses simple clinical measurement and incorporates a wide range of categories it comprises of non-voice quality parameters which is a limitation as it adds on unnecessary information.

The following table 2.1 acts as a guide to select the perceptual voice quality evaluation scheme according to Carding, Carlson, Epstein, Mathieson, & Shewell, (2000).

Table 2.1: Comparison of perceptual rating scales
Source: Carding, Carlson, Epstein, Mathieson, & Shewell, (2000).

	GRBAS	VPA	Buffalo III
Terms based on theoretical framework	Yes (acoustic)	Yes (phonetic)	No
Training prerequisite	No	Yes	No
Applicable to normal voice	No	Yes	No
Abnormality rating	Yes	No	Yes
Audio tapes for listener training	Yes (in Japanese)	Yes (in English)	No
Laryngeal note rating	Yes	Yes	Yes
Vocal tract ratings	No	Yes	No
Prosodic features	No	Yes	Yes
Intra and inter-judge reliability evidence	Yes	Yes	Yes
Number of parameters	5	31	12
Rating range	0-3	Varies according to parameter	1–5
Protocol form	No	Yes	Yes
Time to administer (approximately)	<5 min	10 min	5–10 min
Applicable to voice/Singing teacher	No	Yes	No

Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) Scales

The Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) scales were introduced by American Speech-Language Hearing Association (2002) as a part of standardizing the protocols for auditory evaluation of voice. This was further extended by Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman (2009).

CAPE-V is a visual analog scale which is to be rated on a scale of 1-100mm on the aspects of overall severity, roughness, breathiness, strain, pitch as well as loudness.

As recommended by the authors, these ratings are to be carried out on sustained productions of the vowels /a/ and /i/; six standardized sentences; and also a continuous speech task. The judge is also given space to indicate any other parameter (for e.g., asthenia, diplophonia, tremor, wet/gurgly voice etc.) which has been noticed in the sample being analysed. The task of the judge is to mark a vertical line on the 100mm line depending on the severity of the sample. Also the judge is required to indicate whether the characteristic is present consistently/intermittently.

The major advantage of CAPE-V over other methods of perceptual evaluation of voice is that it specifies the tasks which are to be carried out to rate the severity of voice disorder and that it combines several tasks that increases the efficiency of the rating which is made.

In the Indian context, Gupta & Pushpavathi (2009) attempted to evaluate the reliability of perceptual evaluation of hoarseness of voice for various tasks such as phonation, reading of sentences and spontaneous speech using the CAPE-V. They found that the spontaneous speech sample yields more reliable perceptual rating of voice than the reading of sentences or phonation of sustained vowel.

However, Karnell *et al.,* (2007) examined the reliability of clinician's ratings with CAPE-V, and compared it to those made using the GRBAS (Hirano, 1981) and two other quality of life scales. The study made 4 proficient judges to judge 103 voices using both the scales, voice set balanced by age and severity, judges used both scales in the same sitting and the severity of CAPE-V was compared to that of the Grade of GRBAS scale. The authors reported the presence of very good reliability of overall dysphonic severity with GRBAS and CAPE-V scales by the proficient judges, and that a noble level of consensus was present among the two rating systems.

Further, Zraick *et al.,* (2007) had compared the reliability of the CAPE-V and that of GRBAS scale, suggested that the CAPE-V results equals the GRBAS in measurement reliability. In yet another study by Zraick *et al.,* (2011), the reliability and empirical validity of the CAPE-V when used by skilled voice clinicians (21 raters) rating 22 normal and 37 disordered voices using the CAPE-V and the GRBAS scales were scrutinized. This study reported somewhat better rater reliability with the CAPE-V to arrive at perceptual judgments of voice quality compared to GRBAS scale although it was not significant.

Jesus, Barney, Sa Couto, Vilarinho & Correia, (2009) compared the voice quality in European Portuguese using GRBAS and CAPE-V scale and statistically significant results were revealed across the 'G' rating of GRBAS and Overall severity and roughness from CAPE-V, 'R' rating GRBAS and overall severity in CAPE-V, and 'B' rating in GRBAS and breathiness in CAPE-V. The correlation values were ranged from 0.60 to 0.87 and were found to be good.

One disadvantage of the CAPE-V scale is that the visual analog scale of 1-100mm results in reduced precise test retest reliability. The GRBAS scales has an advantage over the CAPE-V scale in that aspect as the rating is limited to a 4 point scale. Also the administration time for CAPE-V is comparatively longer when compared to GRBAS scale (Nemr *et al.,* 2012).

Mathew & Yeshoda (2014) carried out a study to investigate upon the intra and inter rater reliability of the GRBAS scale in the Indian context. 29 Speech Language Pathologists with minimum of 2 years of clinical experience working across multiple setups such as hospital, institute, school and private served as subjects for her study. She found that the intra rater variability within the raters were less and that reliability was good in all domains of GRBAS except for the Asthenia domain. However, she reported of possible effect of various setups in which Speech Language Pathologists works which could influence the GRBAS ratings.

One major advantage of perceptual evaluation of voice is that it is a means of assessment that is easily available to most of the practicing speech language pathologists and laryngologists for daily use in their clinical setups. Also most of these measures have been found to be reliable and valid (Carding, Wilson, MacKenzie, & Deary, 2009). Several of these scales have been validated for several populations across the globe through a number of studies and are being frequently used by voice clinicians (Nemr *et al*., 2012).

Objective Evaluation of Voice

Although perceptual evaluation of voice is considered as the gold standard while assessing a person with dysphonia, it is vulnerable to a lot of variations which arise due to several listener, subject or task factors. The subjective nature of the perceptual evaluation of voice and its limitations resulted in the emergence of objective measures of voice quality. Objective measures of voice assessment provide a means of quantitative assessment of the quality of voice. It can be both invasive as well as non-invasive. Invasive methods of voice evaluation include the use of videostroboscopy, laryngeal electromyography and some measures of aerodynamic measurement of voice etc. Non-invasive methods of voice evaluation include methods such as Electroglottography (EGG), acoustic evaluation of voice etc. However, several objective measures include the use of complex softwares/instruments and requires training for use as well interpretation.

Acoustic measurements of voice on the other hand, have been used in the assessment of voice due to their advantages such as non-invasiveness and affluence of use. Acoustic measurements, quantifies the degree of severity of dysphonia; which when carefully interpreted can become a useful measure to scale dysphonic severity, to monitor improvements in voice quality with medical or therapeutic management. Acoustic measures have been regarded as the utmost reliable objective measure of voice quality over the perceptual measures. (Carding, Wilson, MacKenzie, & Deary, 2009).

For objective evaluation of the voice quality, several acoustic measures that include frequency related measures (e.g., fundamental frequency, habitual Frequency, frequency range etc.) amplitude related measures (e.g., habitual intensity, extent and fluctuation of intensity etc.), perturbation related measures (e.g., jitter, shimmer, etc.) as well as harmonics related measures (e.g., harmonics to noise ratio etc.) have been widely used by various researchers (Dejonckere & Lebacq, 1996; Hirano *et al*., 1988; Rabinov *et al.*, 1995; Picirillo *et al.*, 1998; Wolfe, Fitch & Cornell, 1995).

Acoustic measures of voice quality provides the clinician with an accurate, precise and quantitative profile of the characteristics of voice being investigated. It has an upper hand over the perceptual evaluation of voice in the fact that they are least subjective and therefore a better reliable method to profile the vocal functioning. Also, acoustical measures tend to provide the clinicians with uniformity in the diagnostic examinations across the practicing clinicians and various clinics.

Despite the advantages of objective measures over perceptual evaluation, it was still considered as inferior to the perceptual evaluation of voice, as the trained ears of the clinician couldn't be replaced by the objective systems. This is evidenced by the poor to moderate correlation in perturbation measurements on investigating inter-device reliability from two voice analysis devices (Bough, Heuer, Sataloff, Hills, & Cater,

1996) and the poor to moderate test retest-reliability as an isolated measure (Carding, Steen, Webb, Mackenzie, Deary & Wilson, 2004). Thus, several researchers became interested in correlating several perceptual measures of voice with that of specific acoustic measures in order to identify which parameters correlates best with the perceptual measures of voice.

Several authors tried to include variety of duration related and aerodynamic measures (for e.g., maximum phonation duration, phonation quotient, airflow, subglottic air pressure etc.) for characterizing the voice quality (Hirano, Hibi, Terasawa & Fujiu, 1986). Following the introduction of computer based systems, there has been a rise in the use of acoustical analysis of voice samples (Baken & Orlikoff, 2000; Rabinov *et al.*, 1995).

Dejonckere & Lebacq (1996) compared across the acoustic measure of jitter and the aerodynamic measure of glottal air leakage with the perceptual measures of harshness, breathiness and roughness in 87 individuals with dysphonia. They concluded that glottal air leakage was associated with production of turbulent noise which gave the perceptual quality of breathiness whereas, the acoustical measure of jitter correlated more with the perceptual quality of roughness.

Rabinov *et al.*, (1995) compared across the acoustic measure of jitter with a 75mm visual analog scale on 50 individuals with voice qualities ranging from normal to severe dysphonia. This investigation revealed that the trained ear of the listeners agreed as equivalent or even more than the objective procedures used. They concluded that the listeners and the objective procedures differ greatly in their measurement characteristics and that reliability should not be a reason to favour acoustic measures of perturbations over perceptual measures.

Giovanni, Revis & Triglia (1999) compared across the acoustic measures of jitter and shimmer and aerodynamic measure of oral air flow with the perceptual measure of severity of dysphonia in a group of 27 patients who undertook phonosurgical management during a 3 month period. They concluded that oral airflow allows for simple, quick and reliable assessment of the outcome of phonosurgery and that it can be used in everyday clinical practice.

Morsomme *et al.,* (2001) compared across the objective measures obtained using a voice analysis software (Evaluation of Vocal Assistant system (EVA), (SQ-Lab, Aixen- Provence, France)) with that of the perceptual measure of GRBAS scale in 28 individuals with dysphonia owing to unilateral vocal cord paralysis and 12 individuals with normal voice quality. These authors found that the grade, roughness and asthenia of the GRBAS scale agreed well with the objective measures which reflect the periodicity of the acoustic signal. They concluded that the perceptual voice characteristic of unilateral vocal cord paralysis is contingent more on the grade, breathiness and asthenia than on the roughness parameter.

Heman-Ackah *et al.,* (2003) investigated on the measures of CPP with the overall severity of dysphonia on 281 patients with voice disorders. This study revealed that the CPP for running speech was a very good indicator and a dependable measure than several other acoustic measures such as jitter, shimmer, and NHR.

Thus, even though several authors have tried to examine the association between individual measures derived through the acoustic evaluation of voice along with the perceptual measures, however, their findings were indecisive (Hirano, 1989; Hillman *et al.,* 1989; Hillman *et al.,* 1990; Revis *et al.,* 1999; Chan & Yiu, 2002; Yiu, & Ng, 2004). The indecisive findings of these studies were reported to the lack of consensus about the perceptual qualities, lack of individual correspondence between perceptual qualities and single acoustic measures as well as heterogeneity of algorithms used to measure the acoustic parameters (Eadie & Doyle, 2005).

Yet another difficulty encountered with the use of single acoustic measures for the assessment of voice quality was that, not one single parameter gets affected all the time for various disorders. Thus, the usage of several individual acoustic parameters did not seem to truly reflect the effects of the disorder on the multiple dimensions of voice. Also most of these single acoustic parameters were found to have limited validity (Awan & Roy, 2006).

Thus even though a surfeit of research exists in identifying the instrumental measure which would predict the perceptual severity of a given sample of voice, there has been inconclusive evidence of any single objective measure which could correlate throughout firmly with the perceptual rating. Some researchers at that point, took a deviation from the traditional method of correlating individual measures with perceptual evaluations and tried to bring about combinations of different objective measures which could correlate strongly with the perceptual measures of voice (Wuyts *et al.*, 2000).

Thus, several researchers have tried to devise a multiparametric protocol to investigate the voice quality, to differentiate between various voice types and levels of dysphonia severity (e.g., Awan & Roy, 2006; Ma & Yiu, 2006; Wuyts *et al.*, 2000; Yu, Ouaknine, Revis, & Giovanni, 2001).

Initially, some of the scholars explored on the usefulness of merging several objective measures in order to define the perceptual severity, and such usefulness was usually assessed by the association among the severity levels of voice perceptually rated by clinicians and the instrumental correlates of the equivalent voice samples. Better agreement rates were expected to represent stronger correlation across the perceptual evaluation and the instrumental measures of voice. In their studies, the concordance between the perceptual as well as the instrumental measurements have been analysed through the use of two different statistics (Giovanni *et al.,* 1996; Picrillo *et al.,* 1998a; Picrillo et al, 1998b; Wuyts *et al.,* 2000; Yu *et al.,* 2001).

Giovanni *et al.,* (1996) merged two acoustic perturbations (jitter and signal to noise ratio) with two aerodynamic (voice onset time and glottal leakage) which were obtained simultaneously using the EVA system in order to envisage the perceptual severity ratings. Perceptual judgment was carried out on a 5-point rating scale from '0' normal to '4' severe. Direct entry discriminant analysis showed that the four instrumental measures together achieved 66.1% (158 out of 239) concordance with perceptual rating of severity. However, this concordance was grounded on samples perceptually rated as '0 (normal)', '2 (moderate)', '3 (intermediate)' and '4 (severe)', and samples rated as '1 (mild)' were not included in the analysis as these samples did not demonstrate noteworthy differences compared to Grade '0' and '2' samples. That is, mildly compromised voice quality was not definitely distinguished by the combination of acoustic as well as aerodynamic aspects used.

Piccirillo, *et al.,* (l998a, l998b) attempted twice to develop a multiparametric voice index to label dysphonia severity. They engaged a multivariate logistic regression procedure to identify a minimum combination consisting of 4 among 14 voice measures. These four measures were sub glottal pressure, phonational frequency range, air flow rate measured at lips and maximum phonation time which could be used to distinguish between dysphonic and normal voices. But, the correlation amongst the mixture of four measures and perceived overall severity was only moderate (r = 0.58).

Yu *et al.,* (2001) obtained 11 aerodynamic and acoustic perturbation parameters using the EVA system. Severity of the sample as indicated perceptually was considered from the overall grade of the GRBAS scale. The authors engaged a stepwise discriminant function analysis to identify a combination of six measures such as frequency range, the estimated sub glottal pressure, from /pa/ string, maximum phonation duration of sustained /a/, signal-to-noise ratio, and fundamental frequency of sustained /a/, and Lyapunov coefficient, which could most clearly distinguish among perceptual severity levels. This combination of parameters correctly anticipated 86% of the perceptual severities. However, the fact that only male participants were included in the investigation restricted the generalizability of the findings to the entire populace with voice disorders.

Thus, from the plethora of acoustic measures that are available, the efforts to converge into a single measure which could reliably point to the existence and severity of a voice disorder, was held up by issues relating to the test-retest reliability and validity, as well as several other confounding factors (Carding, Wilson, MacKenzie, & Deary, 2009). But, several researchers have stated that, the use of multiparametric measurements which combine several objective parameters are better to assess the voice quality than with the use of single parameter measurements (Klein, Piccirillo & Painter, 2000; Yu, Ouaknine, Ravis & Giovanni, 2001; Yu, Revis, Wuyts, Zanaret & Giovanni, 2002; Hartl, Hans, Vaissiere & Brasnu, 2003).

Dysphonia Severity Index (DSI)

Although there have been various parameters used for documenting the voice quality objectively, the Dysphonia Severity Index (DSI) (Wuyts *et al.* 2000) is a multiparametric measurement which has been reported to be a robust measure and been used consistently as an outcome measure in various studies (Timmermans, De Bodt, Wuyts, & Van de Heyning, 2004). DSI considers highest frequency, lowest intensity, Maximum Phonation Time (MPT) as well as jitter to arrive at a numerical value that reflects the voice quality of a given individual. All these parameters have to be combined into a weighted multiparametric regression equation to obtain the DSI value and is thus represented as $DSI = 0.13 \times MPT + 0.0053 \times F_0\ High - 0.26 \times I\text{-}Low - 1.18 \times Jitter\ (\%) + 12.4$ (Wuyts *et al*., 2000).

Wuyts *et al.,* (2000) compared the DSI and GRBAS in normal as well as in disordered population, and found the relationship between the GRBABS and DSI, It is as mentioned as follows:

Grade 0 of GRABS scale corresponds to DSI value of +5.0

Grade 1 of GRABS scale corresponds to DSI value of +1.0

Grade 2 of GRABS scale corresponds to DSI value of -1.4

Grade 3 of GRABS scale corresponds to DSI value of -5.0

Further, Hakkesteegt *et al.,* (2006) examined the association between DSI and GRBAS scale in a different group of patients (n=294) and controls (n=118). Furthermore, it was also investigated whether the DSI can differentiate between a group of patients and control group. The voices of each participants were perceptually evaluated on a grade of GRBAS scale, and the DSI was measured. DSI and the score on G were observed to be akin. The groups of patients with voice complaints were found to have lower DSI scores and higher grade scores on the GRBAS scale when compared to the control group. That is, DSI was significantly lower when the score on grade was higher. They also attempted to calculate the specificity and sensitivity for DSI cut off points to determine whether the DSI is able to discriminate between patient group and the control group. They found maximum sensitivity (0.72) and specificity (0.75) at cut off point of 3.0. The authors therefore concluded that DSI is a suitable tool to objectively quantify the severity of dysphonia.

Awan, Miesemer, and Nicolia (2012) carried out a study in order to determine the intra-subject variability of the DSI by integrating a larger sample of subjects and by investigating the test-retest mean differences and intra-subject variability of DSI as well as its constituent parameters. The DSI and its constituent parameters were acquired from 49 normophonic individuals (21 males and 28 females) aged within 18–25 years. Each subject was tested thrice using DSI with about 1-week break between each sitting. The findings revealed that the average DSI as well as the constituent parameters of high F_0 and MPT were reasonably constant over time whereas Bland-Altman analyses pointed out that the within-subject 1-week test-retest variability as well as the 2-week test-retest variability of the DSI for normophonic individuals could be estimated to be within ±2.27, and within ±2.66 respectively. In addition, weak ICC results showed that higher variability can also be anticipated in the DSI constituent measures of low intensity and jitter. No indication of test-practice influence was seen on repeated DSI probes. The results of this investigation are in concordance with earlier data with respect to the intra-subject variability of the DSI.

DSI was found to correlate with parameters of voice complaints and voice disorders (Kooijman, De Jong, Oudes, Huinck, Van Acht, & Graamans, 2005). Furthermore this index has been used to compare voice quality of different groups of speakers (Timmermans, De Bodt, Wuyts, Boudewijns, Clement, Peeters, & Van de Heyning, 2002) and to assess outcome of voice training programs in adult professional voice users (Timmermans, De Bodt, Wuyts, & Van de Heyning, 2004). As already stated, prior studies done by Wuyts *et al.,* (2000), Hakkesteegt, Brocaar, Wieringa & Feenstra, (2008) and Awan, Miesemer, and Nicolia (2012) revealed that the average DSI values across groups of participants can be extremely unwavering.

Hakkesteegt, Brocaar, Wieringa & Feenstra, (2008), investigated on the inter-observer variability and the test retest reliability of the DSI in 30 non-smoking volunteers without any voice complaints or voice disorders by two speech pathologists. The subjects were measures on 3 different days with an interval of one week. The results revealed that the differences in measurement across the different observers were not significant and the interclass correlation coefficient of the DSI was 0.75 which was considered as good.

Ever since the genesis of DSI, several researchers have tried to investigate the vocal characteristics of several populations (such as professional voice users, Voice disordered individuals, other speech disorders such as cleft palate etc.) using the DSI.

Van Lierde *et al.*, (2004) studied the vocal quality and the effects of gender on vocal quality on 28 children with unilateral or bilateral cleft palate. It was revealed that both the groups of children, i.e., with unilateral as well as bilateral cleft palate had a significantly lower DSI scores than the available normative data. They also found gender related vocal quality differences.

Van Ardenne *et al.*, (2011) tried to assess the vocal outcome of 24 patients who underwent medicalization thyroplasty using silicone and titanium implants and to compare across the two implanted materials using prospective sequential cohort study using the Voice Handicap Index (VHI), the GRBAS scale, Maximum Phonation Time and the Dysphonia Severity Index (DSI). Post-operative analysis of the entire population showed statistically significant improvement in Voice Handicap Index, Maximum Phonation Time, Dysphonia Severity Index and the parameters of G, B, and A of the GRBAS scale. Subgroup analysis revealed a significantly greater improvement of the VHI of the titanium cohort when compared to the silicone cohort. Improvement of maximum phonation time, DSI and GRBAS scale of titanium cohort was greater than improvement of the silicone cohort, even though it was not statistically significant.

Henry *et al.,* (2010) attempted to assess the functional voice outcome post thyroidectomy using DSI, CAPE-V and VHI in 64 patients who underwent thyroidectomy. They reported of significant pre and post thyroidectomy changes in the DSI values.

Awan (2010) investigated on the capability of DSI and its constituent measures to unveil the differences across the vocal capability between groups of young adult female smokers and non-smokers. The study was carried out on a group 30 young female smokers and 30 young female non-smokers within the age range of 18-24 years. It was revealed that significant differences exist between the groups on DSI, with reduced DSI scores for smokers due to the reductions in high F_0 and increases in the Ilow. Significant group differences in the DSI and its constituent measures were reasoned out as early changes in vocal function secondary to smoking.

In the Indian context also, several studies have been carried out using the DSI within the clinical as well as other populations involving professional as well as non-professional voice users, monozygotic twins, etc. These studies have been summarized as follows:

Jayakumar & Savithri (2009) investigated the voice quality of monozygotic twins within the age range of 18-25 years using a combination of qualitative measure of CAPE-V and quantitative measure of DSI. Further comparison was carried out across both these voice quality measurements. They concluded that the voice quality of the monozygotic twins was similar in many of the parameters of the qualitative as well as the quantitative measures.

Neelanjana & Jayakumar (2011), compared DSI scores with that of CAPE-V in individuals with voice disorders. It was revealed that a significant correlation exists between DSI and most of the parameters of CAPE-V even in individuals with voice disorders.

Jayakumar & Savithri (2012) developed the Indian normative for DSI and compared it with the European norms. Evident differences were found between the Indian and European population in terms of Highest F_0, MPT as well as the DSI values. They reasoned the significant reduction in MPT for Indian population would have led to the overall reduction in DSI value in both the genders. However, their findings of females obtaining a higher value on the DSI was a contradiction by the earlier study done by Hakkesteegt *et al.*, (2006). Thus, they caution the voice professionals to reinvestigate and establish their own norms for their geographical and ethnic groups.

Ravibabu & Maruthy (2013) compared across the DSI parameters obtained for trained Carnatic classical singers and non-singers and also investigated the effect of age on DSI. The participants were 30 singers who were subdivided into groups of 15 younger singers below the age of 50 years and 15 older singers above the age of 50 years. The results revealed that singers had significantly higher values of phonation frequency, longer MPT, and higher DSI values. However, when compared to the younger singers, older singers had significantly reduced higher fundamental frequency, MPT, and DSI values. Also it was revealed that singers had better DSI scores when compared to non-singers in both the age groups.

Yeshoda, Rajasudhakar, Jayakumar, Amoolya and Deepthi (2013) investigated on the DSI characteristics of 18 special educators. Among them, 13 were females and 5 were males. Female participants were further sub grouped based on number of years of teaching experience. Group 1 included teachers having less than 8 years of teaching experience and Group 2 included teachers having more than 8 years of teaching experience. The values of DSI parameters of special educators were found to be within normal limits when compared with non-professional voice users except for the highest frequency in female participants. There was no significant difference found between the DSI values of males and females. Years of teaching experience did not have any effect on the parameters of DSI. Teaching children with special needs did not have any effect on the most of the DSI parameters for the special educators in the present study.

Benoy, Binu & Pebbili (2014) compared across DSI parameters obtained for untrained choral singers and those reported earlier in literature for non-singing population. They found that untrained choral singers had a higher DSI value compared to general non-singing population. They also reported of significant gender effect on DSI with females obtaining a higher value of DSI than males. It was revealed that the untrained choral singers had a lower MPT values when compared to the general non-singing population.

Prasad & Geetha (2015) compared across the groups of female prepubertal trained Carnatic classical singers and non-singers using DSI. Thirty female prepubertal Carnatic singers in the age range of 8-10 years with 3-4 years of training in Carnatic singing were considered for the study along with their non-singing counterparts. The results revealed that there was an increase in the DSI scores of Carnatic singers compared to non-singers. It was also found that Carnatic singers had significantly higher MPD and Highest fundamental frequency than non-singers. However, there was no statistically significant difference across the parameters of lowest intensity and jitter across the two groups. Thus, the authors concluded that Carnatic singing training has an effect on DSI parameters extending the findings of the study by Ravibabu & Maruthy (2013) to younger population as well.

Pebbili, Kidwai & Shabnam (2017) reported of DSI values in typically developing children in the Indian context. A total of 42 typically developing children (8–12 years) without complaint of voice problem served as participants for the study. The average DSI values obtained in children were 2.9 (+/-1.23) and 3.8 (+/-1.29) for males and females, respectively. This was provided as the reference data of DSI for typically developing children in the Indian population.

Limitations of DSI

DSI takes into account vocal range which is a parameter, in the true sense, which can be difficult to obtain. It can vary widely over several trials and requires more time and effort. Studies have shown that it takes almost 20 minutes to half an hour to obtain a satisfactory Voice Range Profile (Pabon, 1991; Titze *et al*., 1995). Several researchers have suggested that various procedural variations in obtaining vocal frequency and intensity limits can lead to high inter and intra subject variability (Gramming, Sundberg, & Åkerlund, 1991; Ma *et al.* 2007). Also the Lowest Intensity that is considered for DSI requires high standard instrumentation that gives precise intensity measurement. A high quality Sound Level Meter or such apparatus have been recommended for use to obtain this parameter. But it might not be feasible with majority of commercially available voice diagnostic instruments.

Aichinger, Feichter, Aichstill, Bigenzahn & Schneider-Stickler (2012) investigated on the inter-device reliability of DSI measurement. They found that the DSI values measured across two instruments namely LingWAVES (WEVOSYS, Forchheim, Germany) and DiVAS (XION, Berlin, Germany) showed great differences. The differences in values they obtained across devices for 95% of the subjects were within the limits of -2.39 and -2.82, which makes a clinical interpretation of severity of voice disorder using different devices questionable.

Even though sustained vowels show a lessened variation within the speech signal due to prosodic and voicing factors and permit easier standardization of the sample, connected speech is a more natural speaking behaviour, and is the environment in which perceptual judgments regarding the acceptability of vocal quality are made (Carding, Carlson, Epstein, Mathieson, & Shewell, 2000). However, given the fact that acoustic qualities of sustained phonation, as well as connected speech varies, including a connected speech sample can serve the function of increasing the ecological validity of the analysis. (Wolfe, Cornell & Fitch, 1995; Zraick, Wendel & Smith-Olinde, 2005). Thus arises a necessity to incorporate even connected speech sample within the acoustical analysis so that the sample used to diagnose will be more similar to that of the individuals habitual speaking voice (Reynolds *et al.*, 2012).

Acoustic Voice Quality Index (AVQI)

One recently developed method to quantify the severity of overall dysphonia involving both sustained phonation and connected speech is the Acoustic Voice Quality Index (AVQI) (Maryn *et al.*, 2010). For the purpose of developing AVQI, Maryn and colleagues made use of concatenated samples of sustained vowel as well as connected speech which were subjected to analysis of 13 acoustic measures (based on fundamental frequency perturbation, amplitude perturbation, spectral and cepstral analyses). Following this, stepwise multiple linear regression analysis was applied and a six-variable acoustic model for the multiparametric measurement of overall voice quality of the concatenated samples was derived. This consisted of weighted combination of time, frequency and quefrency domain metrics (with a cepstral measure being the main contributor for the prediction of overall voice quality)

The parameters used for AVQI are, smoothed cepstral peak prominence (CPPS), harmonics-to-noise ratio (HNR), shimmer local (SL), shimmer local dB (ShdB), slope of the long-term average spectrum (slope) and tilt of the trendline through the long-term average spectrum (tilt). Thus AVQI is constructed as AVQI = 2.571*(3.295-0.111*CPPS - 0.073*HNR - 0.213*SL + 2.789*ShdB - 0.032*Slope + 0.077*Tilt) (Maryn *et al.*, 2010). A score of 2.95 or below obtained on AVQI identifies the sample to be normophonic for Dutch speakers (Maryn *et al.*, 2010). According to Maryn *et al.*, (2010), the reported sensitivity and specificity values of AVQI were 0.85 and 1.0 respectively.

Maryn *et al.*, (2010) found that a positive relationship exists between AVQI and perceptual dimension of overall dysphonia, and thus, the higher an AVQI score, the more disrupted the overall voice quality and vice versa. The correlation between the outcome of AVQI and the perceptual dimension of overall dysphonia was found to be 0.78, which demonstrates a high concurrent validity (Maryn *et al.*, 2010).

As AVQI involves the use of concatenated samples of continuous speech and phonation simultaneously, there was a need to identify whether it was stable across different phonetic and linguistic structures across languages. For this purpose studies on several languages such as English, Dutch, French, German, Japanese, Korean, Lithuanian etc. were carried out by several researchers and the results are summarized in table 2.2 as follows:

Table 2.2: Summary of AVQI scores across different languages reported in the literature.

Language	Author	Threshold of AVQI values
English	Reynolds *et al.,* (2012)	3.46
	Maryn *et al.,* (2014)	3.25
Dutch	Maryn *et al.,* (2010)	2.95
	Barsties & Maryn (2015)	2.80
French	Maryn *et al.,* (2014)	3.07
German	Barsties & Maryn (2012)	2.70
Japanese	Hosokawa *et al.,* (2017)	3.15
Finnish	Kankare *et al.,* (2015)	2.35
Lithuvanian	Uloza *et al.,* (2017)	2.97

Thus AVQI was identified as stable across different phonetic and linguistic structures across several languages such as English, Dutch, Finnish, French, German, Japanese, Lithuanian etc. even though it involves continuous speech as one of the measures that contributes to it (Maryn *et al*. 2010a, 2010b, 2014; Reynolds *et al.*, 2012; Barsties & Maryn, 2012, Hosokawa *et al.*, 2017). Also, recent studies revealed a strong correlation of AVQI with the GRBAS scores as well as that of CAPE-V for Korean (Maryn, Kim, & Kim, 2016) as well as for Lithuanian (Uloza *et al.*, 2017) languages.

In a study by Reynolds *et al.*, (2012) it was revealed that AVQI has high diagnostic accuracy concerning its applicability to the paediatric voice. They found that, AVQI correlates with GRBAS scale and that AVQI is an appropriate tool for assessment and diagnosis of voice disorders in children.

Also, AVQI was found to be sensitive to treatment related changes, validating its role as a potentially robust and objective voice treatment outcomes measure also (Maryn, De Bodt, & Roy, 2010). AVQI has been used to document the effects of voice therapy on voice quality in a variety of population including children (Reynolds *et al.*, 2016), and adults with several voice disorders (Hosokawa *et al.*, 2017, Uloza *et al.*, 2017).

In a recent study by D'haeseleer, Meerschman, Claeys, Leyns, Daelman, & Van Lierde, (2016), an attempt was made to profile the voice of Dutch theatre artists using AVQI. Acoustic analysis carried out using AVQI revealed a mean value of 3.48 corresponding to a mild dysphonia. Fifty percent of the theatre actors testified as having (occasionally or often) vocal complaints subsequent to performances. They also identified occurrence of vocally violent behaviour and pitiable vocal hygiene practices.

In the study by Hosokawa *et al.,* (2017), the concurrent validity, receptiveness to change, and diagnostic accurateness of the AVQI were assessed in a group of individuals with voice disorders pre and post therapy as a retrospective investigation. They found that the concurrent validity and receptiveness to change depending on the total voice quality was high with the correlation coefficients being 0.828 and 0.767, respectively. Also, the receiver operating characteristic(ROC) analysis demonstrated an excellent diagnostic accuracy with respect to discernment across voices of individuals with dysphonia and voices of individuals with no voice disorders (area under the curve: 0.905).

The above mentioned studies demonstrate the applications of AVQI in several clinical populations ranging from children to adults, speakers of different languages, professional voice users and other individuals with voice disorders. Thus, in the present scenario of voice sciences, AVQI evidences as an incipient role as a promising voice measurement tool.

Ever since its genesis, AVQI was calculated using a combination of *SpeechTool* (used to derive CPPS) (James Hillenbrand, https://homepages.wmich.edu/~hillenbr/) and *Praat* (for the acoustic measures of HNR, SL, ShdB, Slope, & Tilt) (Paul Boersma and David Weenink, http://www.praat.org/) which was a tedious process. However, with the implementation of CPPS within Praat, AVQI could be determined by the use of *Praat* software alone.

A study by Maryn & Weenink (2015) established that the $CPPS_{Praat}$ is a highly acceptable approximation of the $CPPS_{SpeechTool}$. They derived the beta version of AVQI (AVQI Version 02.02) which was defined as AVQI= 9.072 - 0.245*CPPS - 0.161*HNR - 0.470*SL + 6.158*ShdB -0.071*Slope + 0.170*Tilt. The alpha version as well as the beta version of AVQI were found to be akin, thus increasing the clinical practicality of both methods as measures of dysphonia severity.

From the review of literature it is evident that the AVQI is a promising measure for the assessment of voice. However, at present there are no studies in the Indian context which serves as the reference measure for the Indian languages. Given that the Dravidian languages of Malayalam and Kannada are totally different from the languages so far investigated using the AVQI in Europe and eastern Asia in terms of its syllabic structure and other inherent characteristics, one cannot presume that similar results would be observed for these two languages without probing into them and without developing the reference measures for these languages. Thus the present study aims at reporting reference values for the AVQI on Malayalam and Kannada speaking Indian population and to compare it with the perceptual measure of GRBAS scale as well as to compare the AVQI scores and perceptual measure of GRBAS in the dysphonic Indian population.

CHAPTER 3

METHOD

Present study was carried out to develop reference data for AVQI and to validate AVQI with perceptual measure (GRBAS scale). The methodology adopted were as follows:

Participants

A total of 120 individuals were enrolled for the study of whom 100 were individuals with normal voice quality and 20 were individuals with dysphonia. These participants were further subdivided into three major groups. Group I consisted of 50 individuals who were native Malayalam speakers (Mean age of 33.06 ± 9.38). Group II consisted of 50 individuals who were native Kannada speakers (Mean age of 34.28 ± 9.63), and group III consisted of 20 individuals with mild to moderate dysphonia (Mean age of 35.4 ± 9.29). All the participants of the study were in the age range of 20-50 years. The participants of the third group were diagnosed as having dysphonia by a speech language pathologist as well as an otolaryngologist. They were also classified on the degree of severity as either having mild or moderate degree of dysphonia by a speech language pathologist.

The participants of first two groups were further classified into two subgroups based on the age of the participants; a lower age range (20-35 years) and a higher age range (35-50 years). All three groups and its subgroups had equal males and female participants, the details of which are given in the table 3.1 below.

Table 3.1: Details of participants of Group I and Group II.

Age Range (in years)	Group I Malayalam (n=50)		Group II Kannada (n=50)	
	Male (n=12)	Female (n=13)	Male (n=12)	Female (n=13)
20-35 years	25.50 (± 4.48)	24.08 (± 3.90)	25.58 (± 3.89)	25.92 (± 5.02)
35-50 years	41.75 (± 4.13)	41.15 (± 4.56)	42.42 (± 4.16)	43.15 (± 4.61)

The details of the participants of the group III (n=20) and their classification based on their severity of dysphonia are as mentioned in the tables 3.2 and 3.3 given below:

Table 3.2: Details of participants of Group III

Gender	Mean age	
	Mild	Moderate
Male (n=10)	32.75 (± 10.21) (n=4)	33.67 (±9.97) (n=6)
Female (n=10)	36.83 (±11.63) (n=6)	38.5 (±4.35) (n=4)

Table 3.3: Diagnostic details of participants of Group III.

No.	Age	Gender	ENT/Stroboscopic findings	Provisional Diagnosis
101	36	Female	Right vocal cord cyst	Moderate Hoarse Voice
102	33	Male	Bilateral sulcus vocalis with muscle tension dysphonia type III	Moderate Hoarse Voice
103	43	Male	Laryngitis	Mild Hoarse Voice
104	40	Male	Muscle tension dysphonia type III	Mild Hoarse Voice
105	24	Male	Right vocal cord paralysis	Moderate Hoarse Voice
106	36	Female	Bilateral sulcus vocalis with muscle tension dysphonia type III	Moderate Hoarse Voice
107	30	Female	Bilateral vocal nodule	Mild Hoarse Voice
108	38	Male	Right vocal nodule	Moderate Hoarse Voice
109	50	Female	Muscle tension dysphonia type III	Mild Hoarse Voice
110	42	Female	Early nodular changes	Mild Horse Voice
111	20	Male	Bilateral vocal nodules	Moderate Hoarse Voice
112	24	Female	Glottic Chink with muscle tension dysphonia type III	Mild Hoarse Voice
113	49	Female	Glottic chink with muscle tension dysphonia type III	Mild Hoarse Voice
114	45	Female	Left vocal cord polyp	Moderate Hoarse Voice
115	23	Male	Muscle tension dysphonia type III	Mild Hoarse Voice
116	25	Male	Sulcus vocalis with glottic chink	Mild Hoarse Voice
117	37	Female	Right vocal cord palsy	Moderate Hoarse Voice
118	26	Female	Glottic chink	Mild Hoarse Voice
119	45	Male	Bilateral vocal nodules	Moderate Hoarse Voice
120	42	Male	Right vocal cord polyp	Moderate Hoarse Voice

Inclusionary criteria for group I & II

- Participants were native speakers of Malayalam or Kannada language.
- Participants of group I should have normal quality of voice

Exclusionary criteria for group I & II

- Participants, who had upper respiratory tract infection, asthma, or allergic diseases at the time of recording were excluded from the study.
- Also participants with the history of neurological, speech or language disorders were excluded from the group of individuals with normal voice quality.
- Participants with history of alcohol consumption or smoking and tobacco usage were excluded from the group of individuals with normal voice quality.

Stimuli

Samples of sustained phonation of vowel /a:/ for a minimum duration of 5 seconds, and continuous reading speech (using standard passages of Indian languages such as Kannada and Malayalam (Savithri & Jayaram, 2005) (Appendix)) sample were used as stimuli for all three groups participated in the study.

Procedure

Before the recording, the participants were explained of the procedure and an informed consent was taken. They were asked to sit straight in a relaxed manner. Microphone of the recorder was placed 6cm away from the mouth of the participant to avoid breathing noise. The audio recordings were obtained in a quiet room using Olympus LS 100 digital voice recorder, with a sampling frequency of 44.1 KHz and 16 bit resolution in .wav format. Same recording settings were used for the recording of both sustained vowel and continuous speech. Three trials of sustained vowel as well as two trials of the continuous speech were recorded. The best trial was considered for the analysis.

Analysis

AVQI

The obtained audio recordings were subjected to objective analysis using *Praat* script to obtain AVQI. The script for obtaining AVQI (v02.02) published by Maryn & Weenik (2015), that contained the formula, AVQI= 9.072 - 0.245*CPPS - 0.161*HNR - 0.470*SL + 6.158*ShdB -0.071*Slope + 0.170*Tilt was used. For the sustained vowel /a:/ the stable middle 3 second portion was extracted and the third to fifth sentences of the paragraphs were used for continuous reading speech sample. The extracted samples in .wav format were renamed as ‘sv’ (sustained vowel) and ‘cs’ (continuous speech) to be fed into the AVQI script as recommended by Maryn *et al.*, (2010) and Maryn & Weenik (2015). For the purpose of reliability 20% of the data was collected twice and analyzed.

The AVQI output obtained on *Praat* for an individual with normal voice quality is depicted in figure 3.1.

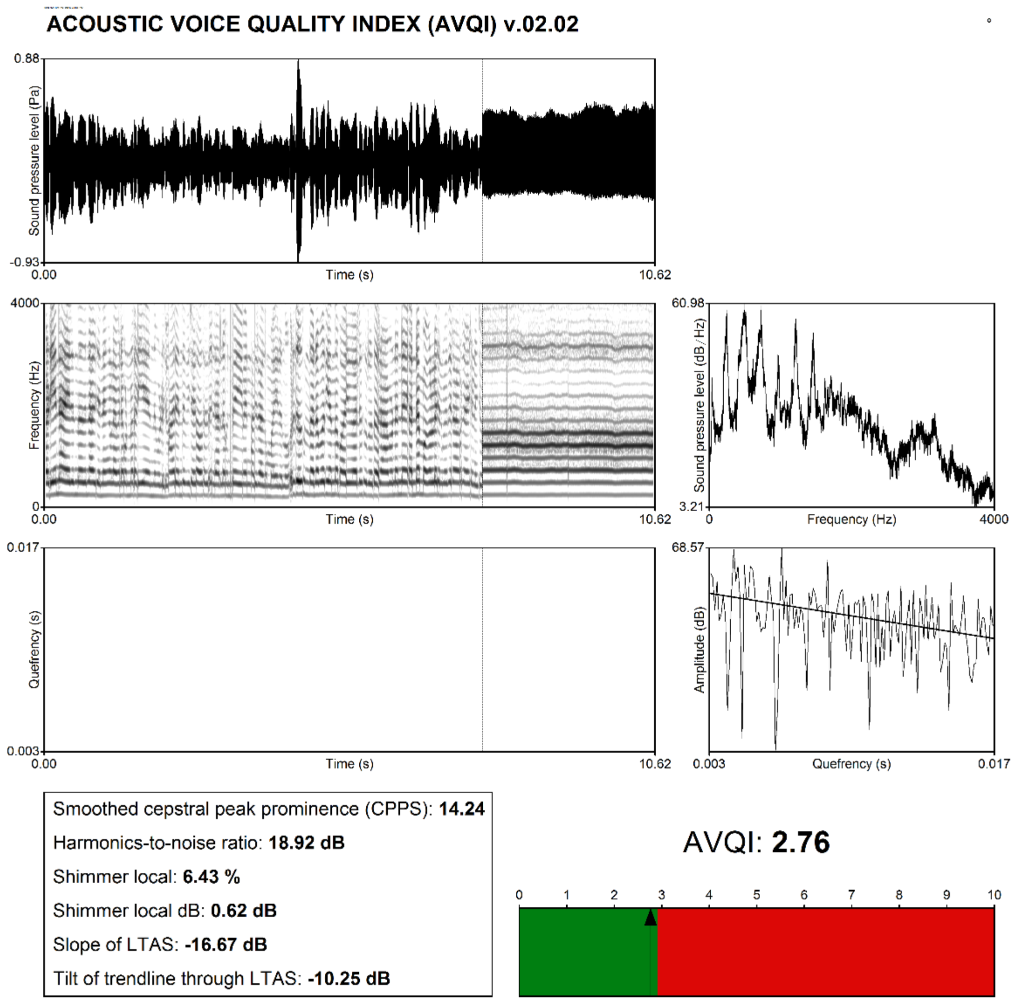

Fig 3.1. Example of graphical output of AVQI outcome of *Praat* Script for AVQI for a normal individual

Similarly, the AVQI output for an individual with dysphonia is depicted in figure 3.2.

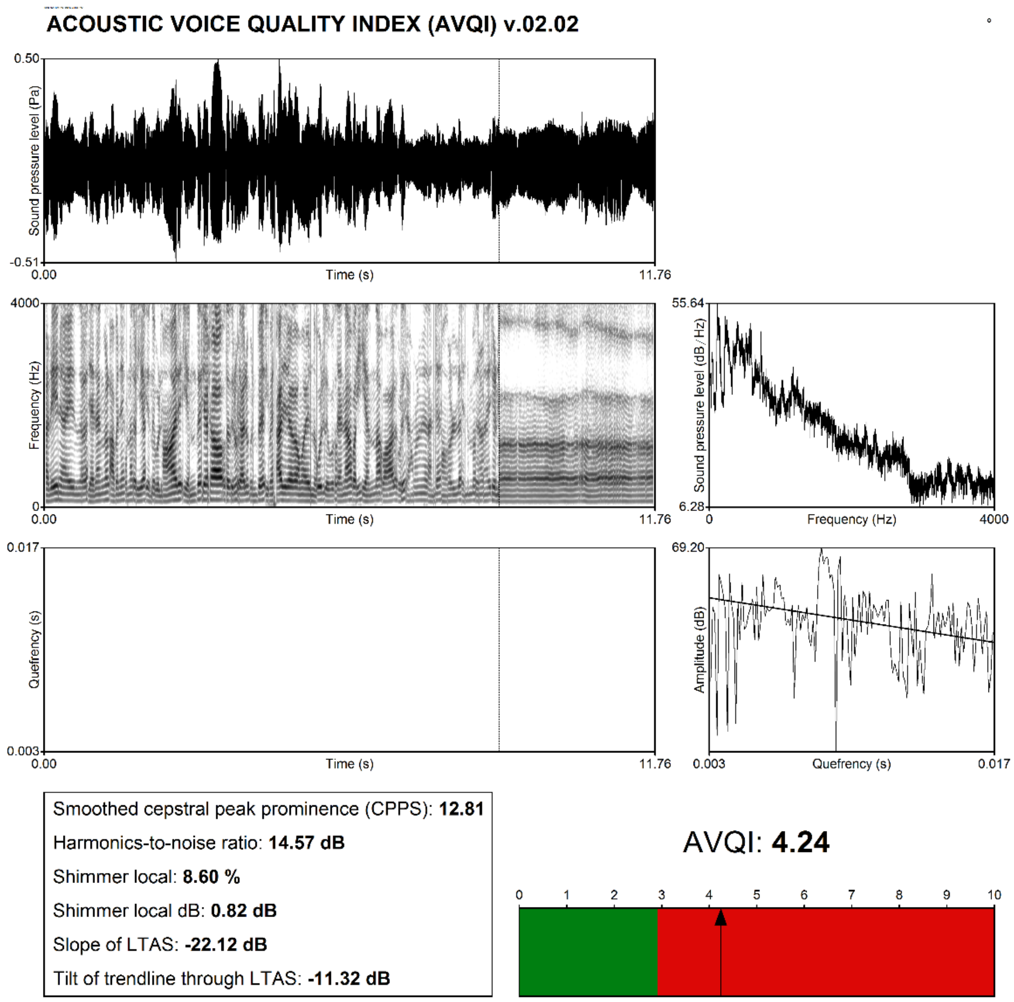

Fig 3.2. Example of graphical output of AVQI outcome of *Praat* Script for AVQI for an individual with dysphonia

Perceptual Analysis

The same samples of sustained vowel and reading sample were used for perceptual analysis and five experienced speech language pathologists served as judges for perceptual evaluation. The judges had a minimum of four years of experience in voice assessment and management following their completion of Post Graduate degree in Speech- Language Pathology and were also currently involved in clinical practice with voice disorders. All the judges were blindfolded regarding the identity and diagnosis of the persons from whom samples were obtained. The voice samples were presented randomly through the headphones in a silent environment. They were asked to rate the quality of voice based on a four point rating scale (0-3) of the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scales. 12 samples (10%) were repeated randomly to check for the intra-judge reliability. The mode value of rating of the five SLPs for a given sample was used to compare with the AVQI values.

Same procedure was carried out for all three the groups of participants. Once the AVQI scores and perceptual analysis scores were obtained, they were compared using appropriate statistical analyses using Statistical Package for Social Sciences (SPSS) Version 20.

Statistical Analysis

The obtained AVQI values for the participants of three groups along with the perceptual measures on GRBAS scale as rated by the judges were subjected to statistical analysis using SPSS (Version 20), in order to derive:

- ✓ The test-retest reliability of Acoustic Voice Quality Index using Cronbach's alpha measures.
- ✓ Intra and inter judge reliability of all constituent parameters of GRBAS scale across and within the judges using Cronbach's alpha measures.
- ✓ Normality of the sample selected for the study using Shapiro-Wilk test for normality.
- ✓ The reference measures for AVQI and its constituent parameters for individuals with normal voice quality and individuals with dysphonia using descriptive statistics.

- ✓ The differences across the groups with respect to AVQI scores and the effect of age, language and gender on AVQI scores using independent *t*-tests.
- ✓ The effects of age, language and gender on individual parameters of AVQI using Multivariate Analysis of Variance (MANOVA).
- ✓ Perceptual ratings using GRBAS of normal as well as dysphonic population using descriptive statistics.
- ✓ Correlation of AVQI with the 'G' of GRBAS scale across all the participants and correlation of constituent parameters of AVQI with that of 'G' of GRBAS scale using Spearman's rank order correlation.

CHAPTER 4

RESULTS

This particular study was focused to develop reference data for AVQI and to validate AVQI with perceptual measure (GRBAS scale). The results of this study will be discussed under the following headings:

- ✓ Test-retest reliability of Acoustic Voice Quality Index.
- ✓ Inter and intra judge reliability of GRBAS scale.
- ✓ Normality check for the data.
- ✓ Mean, standard deviation and range of AVQI and its constituent parameters.
- ✓ Effect of gender, language and age on AVQI and its constituent parameters.
- ✓ Comparison of normal Vs dysphonic population with respect to AVQI
- ✓ Perceptual ratings using GRBAS of normal as well as dysphonic population.
- ✓ Correlation of AVQI with GRBAS scale.
- ✓ The reference measures for AVQI and its constituent parameters

Test-retest reliability of Acoustic Voice Quality Index (AVQI)

In order to obtain the test-retest reliability of the AVQI and its constituent parameters, 20% of randomly selected subjects were asked to repeat the procedure of phonation as well as reading sample. The reliability coefficient (Cronbach's alpha-α) was calculated using SPSS. Table 4.1 shows the test retest reliability of AVQI and its constituent parameters. All the parameters exhibited a very good cronbach's alpha (α) value. Given that the cronbach's alpha (α) measures for every parameter was found to be above 0.9, it is indicated that the AVQI and its constituent parameters are reliable measures.

Table 4.1 Test-retest reliability of AVQI and its constituent parameters

Sl. No.	Parameter	Reliability coefficient (α)
1.	CPPS	0.963
2.	HNR	0.936
3.	Shim Local	0.924
4.	Shim dB	0.931
5.	Slope LTAS	0.950
6.	Tilt LTAS	0.877
7.	AVQI	0.973

α = Cronbach's reliability coefficient

Inter and intra judge reliability GRBAS scale

Table 4.2 illustrates the inter judge reliability of the constituent parameters of the GRBAS scale. Cronbach's alpha (α) coefficient was computed for reliability between judges for each of the parameter of GRBAS. All the five parameters of GRBAS showed very good cronbach's alpha (α) value with the raters agreeing maximally for Grade parameter with its reliability coefficient α being 0.972. The lowest reliability coefficient was obtained for the parameter of asthenia with α being 0.877. However, it can be concluded that the overall inter rater reliability is good for all the parameters of GRBAS.

Table 4.2 Inter-judge reliability of GRBAS parameters

Sl. No.	Parameter	Reliability coefficient (α)
1.	Grade	0.972
2.	Roughness	0.917
3.	Breathiness	0.914
4.	Asthenia	0.877
5.	Strain	0.912

α = Cronbach's reliability coefficient

Similarly, intra judge reliability within each judge, across each parameter of GRBAS was also calculated using cronbach's α. For this purpose 10% of the samples were rated twice by each of the judges. Table 4.3 depicts the intra judge reliability across each parameter of GRBAS. It was found that a good intra judge reliability exists for each of the constituent parameters of GRBAS.

Table 4.3 Intra-judge reliability of GRBAS parameters

Sl. No	Parameter	Judge 1 α	Judge 2 α	Judge 3 α	Judge 4 α	Judge 5 α
1.	Grade	0.966	1.000	1.000	1.000	0.965
2.	Roughness	0.966	1.000	1.000	0.910	0.956
3.	Breathiness	1.000	1.000	0.950	1.000	1.000
4.	Asthenia	0.970	0.900	0.889	1.000	1.000
5.	Strain	0.923	0.974	0.919	0.956	1.000

α = Cronbach's reliability coefficient

Normality check for the data

In order to determine the normality of the sample selected for the study Shapiro Wilk's test was carried out with respect to the independent variables gender, language and age group. It was revealed that all the parameters followed normal distribution with $p>0.05$ except ShimdB for the age groups 20-35 ($p=0.04$) and 35-50 ($p=0.005$) and for the languages Malayalam ($p=0.011$) and Kannada ($p=0.007$).

Mean, standard deviation and range of AVQI and its constituent parameters

AVQI and its constituent parameters were obtained from a total of 100 individuals with normal voice quality and 20 individuals with dysphonia. Table 4.4

depicts the mean and standard deviation of AVQI and its constituent parameters for individuals with normal voice quality as well as individuals with dysphonia. Mean value of AVQI for individuals with normal voice quality was found to be 3.03 (±0.32). Individuals with dysphonia obtained a higher AVQI value of 4.79 (±0.97) compared to the normal individuals. It is worth noting that the standard deviation of the AVQI value is almost thrice as high for dysphonic population compared to that of normal individuals.

Table 4.4 Mean and SD of AVQI and its constituent parameters for normal and dysphonics.

Parameter	**Normal individuals (n=100)**		**Individuals with dysphonia (n=20)**	
	Mean (±SD)	Range	Mean (SD)	Range
CPPS	13.94 (±1.35)	10.78 – 16.77	11.66 (±2.12)	8.45 – 15.9
HNR	18.10 (±2.07)	11.58 – 22.61	16.96 (±2.27)	11.42 – 20.58
ShimLocal	6.45 (±2.07)	3.53 – 12.38	7.70 (±2.30)	4.59 – 13.61
ShimdB	0.68 (±0.12)	0.48 – 1.08	0.80 (±0.17)	0.57 – 1.21
Slope LTAS	-20.21(±3.81)	-28.61 – -10.55	-25.36 (±4.59)	-33.74 – -17.96
Tilt LTAS	-10.82(±0.87)	-12.96 – -8.35	-10.56 (±0.78)	-11.88 – -8.44
AVQI	3.03 (±0.32)	2.29 – 3.76	4.79 (±0.97)	3.37 – 6.26

Effects of gender, language and age group on AVQI

Multivariate Analysis of Variance (MANOVA) was carried out to see the significant differences across gender, language and age group of the constituent parameters of AVQI for the group of individuals with normal voice quality and also to check the interaction effects.

Tests of between subject effects revealed that, HNR F (1, 92) = 9.258, (p = 0.003) as well as ShimLocal F (1, 92) = 4.431, (p = 0.038), demonstrated significant effects across the languages. Also, HNR F (1, 92) = 38.82, (p = 0.000), demonstrated significant effects across the genders. However, no significant differences were found across the age groups.

Similarly, no significant interaction effect was noticed across age group, gender and language for AVQI and its constituent parameters.

Effects of gender on AVQI

Further independent samples *t*-test was carried out to observe for gender effect within the subject groups as well as language and age groups. AVQI value did not show any significant difference with respect to the genders in any of the language groups or age groups t (98) = 0.175, (p=0.86).

The overall results of independent samples *t*-test to determine gender effects on normal individuals are summarized in table 4.5.

Table 4.5 Mean, SD, *t*-value and *p*-value for between gender groups for normal individuals

Parameters	Male[#] (Mean ±SD)	Female[$] (Mean ±SD)	*t*(df)	*p*-value
CPPS	14.08 (±1.29)	13.81 (±1.40)	t(98) = 0.993	0.323
HNR	17.00 (±1.94)	19.12 (±1.62)	t(98) = -5.913	0.000*
ShimLocal	6.78 (±1.78)	6.14 (±1.73)	t(98) = 1.818	0.072
ShimdB	0.70 (±0.12)	0.68 (±0.11)	t(98) = 1.125	0.067
Slope LTAS	-20.97 (±3.48)	-19.50 (±4.00)	t(98) = -1.948	0.54
Tilt LTAS	-10.85 (±0.88)	-10.79 (±0.87)	t(98) = -0.392	0.696
AVQI	3.04 (±0.31)	3.03 (±0.32)	t(98) = 0.175	0.861

* Significant at 0.05 level, # n= 48, $ n=52

In the group of individuals with dysphonia it was revealed that neither AVQI nor its constituent parameters varied with respect to gender.

Thus, no gender effect was observed on the AVQI value and its constituent parameters for normal and dysphonic individuals except for HNR values and further, it was considered as a whole to see the effect of language as well as subject groups on AVQI and its constituent parameters.

Effects of language on AVQI

Independent samples *t*-test was carried out to observe for effect of language within the age groups. AVQI value did not show any significant difference with respect to the language in any of the age groups, *t* (98) = -1.040, (*p* = 0.301). However, the constituent parameters of HNR *t* (48) = -2.859, *(p* = 0.006) as well as ShimLocal *t* (48) = 3.024, *(p* = 0.004) and ShimdB *t* (48) = 2.362, *(p* = 0.022) were found to have significant differences across the two languages for normal individuals. These effects of language on AVQI for the age group of 20-35 is summarized in the table 4.6.

Table 4.6 Mean, SD, *t*-value and *p*-value for between language groups in 20-35 year old normal individuals

Parameters	**Malayalam# (Mean ±SD)**	**Kannada# (Mean ±SD)**	***t*(df)**	***p*-value**
CPPS	13.37 (±1.45)	13.98 (±1.22)	*t*(48) = -1.615	0.113
HNR	17.61 (±1.38)	19.00 (±1.98)	*t*(48) = -2.589	0.006*
ShimLocal	6.72 (±1.70)	5.46 (±1.18)	*t*(48) = 3.024	0.004*
ShimdB	0.69 (±0.11)	0.62 (±0.081)	*t*(48) = 2.362	0.022*
Slope LTAS	-20.96 (±4.44)	-20.68 (±3.87)	*t*(48) = -0.235	0.815
Tilt LTAS	-10.69 (±0.99)	-10.94 (±0.92)	*t*(48) = 0.900	0.373
AVQI	3.00 (±0.40)	3.03 (±0.24)	*t*(48) = -0.335	0.739

* Significant at 0.05 level, # n= 25

As significant gender effects were noted for the constituent parameter of HNR earlier, the language effect on HNR was checked separately for both the genders using independent samples *t*-test. The results are summarized in table 4.7. It was found that, females had a significant difference across language groups *t* (50) = -2.598, (*p* = 0.012) whereas males did not show any such significant differences across the language groups on the parameter of HNR.

Table 4.7 Mean, SD, *t*-value and *p*-value for HNR across languages and gender

HNR / Gender	**Malayalam** # **(Mean ±SD)**	**Kannada**# **(Mean ±SD)**	***t*(df)**	***p*-value**
Males	16.52 (±2.21)	17.48 (±1.54)	*t*(46) = -1.735	0.089
Females	18.56 (±1.37)	19.67 (±1.69)	*t*(50) = -2.598	0.012*

* Significant at 0.05 level, # n= 50

Effect of age group on AVQI

On independent samples *t*-test, no significant differences were found across the age groups for AVQI value for normal individuals, *t* (98) = -0.530, (*p* = 0.597) and the constituent parameters of AVQI as well. The effect of age group on AVQI for normal individuals has been tabulated in table 4.8. Similarly, no significant effect across age groups were observed within the group of individuals with dysphonia for AVQI as well as its constituent parameters.

Table 4.8 Mean, SD, *t*-value and *p*-value for between age groups for normal individuals

Parameters	**20-35 years#** **(Mean ±SD)**	**35-50 years#** **(Mean ±SD)**	***t*(df)**	***p*-value**
CPPS	13.67 (±1.36)	14.21 (±1.29)	*t*(98) = -1.770	0.055
HNR	18.31 (±1.83)	17.90 (±2.28)	*t*(98) = 0.989	0.325
ShimLocal	6.09 (±1.58)	6.81 (±1.90)	*t*(98) = -1.060	0.050
ShimdB	0.65 (±0.10)	0.70 (±0.13)	*t*(98) = -1.823	0.052
Slope LTAS	-20.82 (±4.12)	-19.59 (±3.41)	*t*(98) = -1.630	0.106
Tilt LTAS	-10.82 (±0.95)	-10.82 (±0.79)	*t*(98) = 0.028	0.977
AVQI	3.02 (±0.33)	3.05 (±0.31)	*t*(98) = -0.530	0.597

* Significant at 0.05 level, # n= 50

Comparison of normal Vs dysphonic population with respect to AVQI

Since no language and gender effect were found across the AVQI scores for normal individuals, 2 way ANOVA was carried out to see the main effects of age groups as well as subject groups (normal vs. dysphonic) on AVQI. Interaction effects of subject group as well as age were also checked on. Tests of between subject effects revealed that there was significant across the subject groups F (1, 116) = 202.74, (p = 0.000) as well as age groups F (1, 116) = 7.032, (p = 0.009). Also a significant interaction effect of age group as well as subject group was noticed F (1, 116) = 5.584, (p = 0.00=20).

Since there was an interaction effect noticed between the age groups and subject groups, independent samples *t*-test was carried out results of which are summarized in table 4.9. Normal individuals obtained a mean value of 3.02 (±0.33) for the younger age group and 3.05(±0.31) for the older age group. However, individuals with dysphonia obtained higher AVQI values (4.43 (±0.79) for younger age group and 5.03 (±1.03) for the older age group) compared to the individuals with normal voice quality across both the age groups. It was revealed that there is a significant difference with respect to age groups across normal individuals and individuals with dysphonia in 20-35 year old individuals with *t* (56) = -8.831, (*p* = 0.000) and also in 35-50 year old individuals with *t* (60) = -11.696, (*p* = 0.000).

Table 4.9 Mean, SD, *t*-value and *p*-value for AVQI between subject groups and age groups

AVQI / Age group	Normal individuals# (Mean ±SD)	Individuals with dysphonia (Mean ±SD)	*t*(df)	*p*-value
20-35 years	3.02 (±0.33)	4.43 (±0.79)$	*t*(56) = -8.831	0.000*
30-50 years	3.05 (±0.31)	5.03 (±1.03)^	*t*(60) = -11.696	0.000*

* Significant at 0.05 level, # n= 50, $ = 8, ^ = 12

Further, independent samples *t*-test was carried out to reveal any significant effect of AVQI between subject groups and age groups. It was revealed that the older age group had a higher mean AVQI value of 5.03 (±1.03) compared to the younger age group 4.43 (±0.79) though it was not statistically significant. Such a difference was not noticed in the group of individuals with normal voice quality. Table 4.10 below depicts the differences across age groups within the subject groups.

Table 4.10 Mean, SD, *t*-value and *p*-value for AVQI between age groups within subject groups

AVQI Age group / Subject group	20-35 years (Mean ±SD)	30-50 years (Mean ±SD)	*t*(df)	*p*-value
Normal individuals#	3.02 (±0.33)	3.05 (±0.31)	*t*(98) = -0.530	0.597
Individuals with dysphonia	4.43 (±0.79)$	5.03 (±1.03)^	*t*(18) = -1.379	0.185

* Significant at 0.05 level, # n= 50, **$** = 8, **^** = 12

The subject group as well as age group differences on AVQI scores are depicted in figure 4.1.

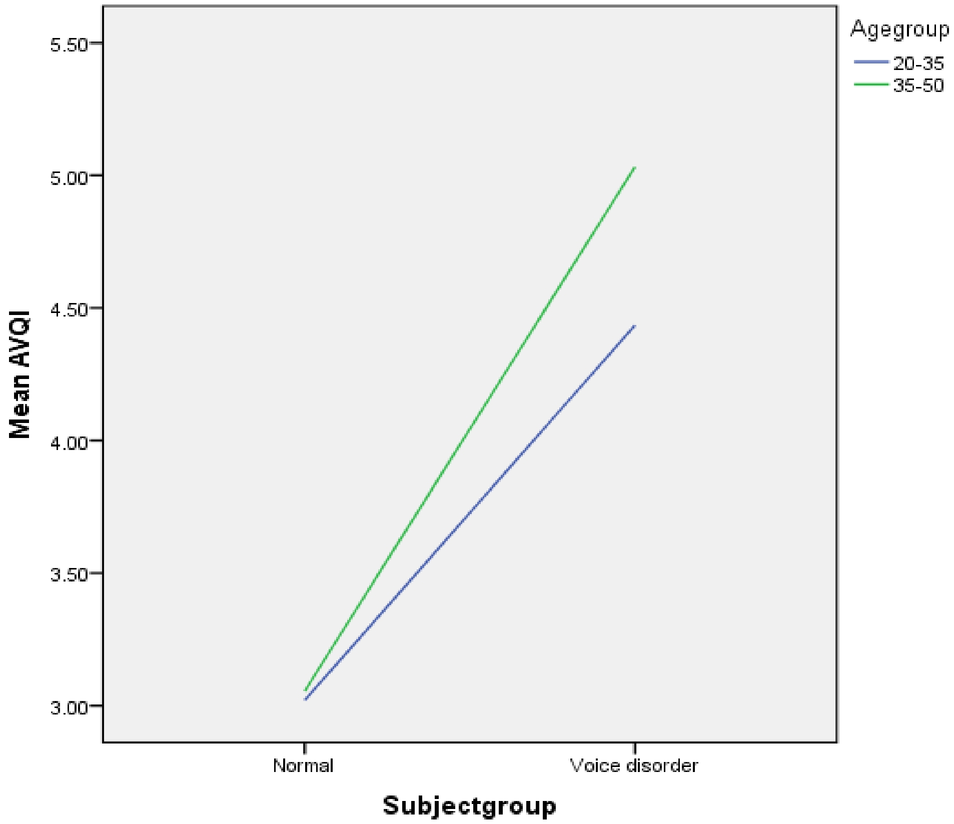

Figure 4.1 Subject group and age group differences on AVQI scores

Perceptual ratings using GRBAS

The obtained samples were subjected to perceptual analysis using GRBAS scale by 5 experienced Speech-Language Pathologists. The results of the perceptual rating using the GRBAS scale is summarized in the table 4.11 below:

Table 4.11 Results of perceptual ratings for the subject groups using GRBAS scale

	Normal individuals (n=100)		**Dysphonic individuals (n=20)**	
	Mode	Range	Mode	Range
Grade	0	0 – 1	1 & 2	1 – 2
Roughness	0	0 – 1	1	0 – 2
Breathiness	0	0 – 1	1	0 – 2
Asthenia	0	0 – 1	1	0 – 2
Strain	0	0 – 1	1	0 – 3

Figure 4.2 depicts the plots for and 'G' and 95th confidence interval for AVQI values for individuals with normal voice quality as well individuals with different degrees of dysphonia. The 95% confidence interval of AVQI shows a clear trend. The variability of AVQI values is found to be limited for individuals with a normal rating of 'G' of GRBAS scale. However, as the 'G' rating on the GRBAS increased, the more variable the AVQI values became.

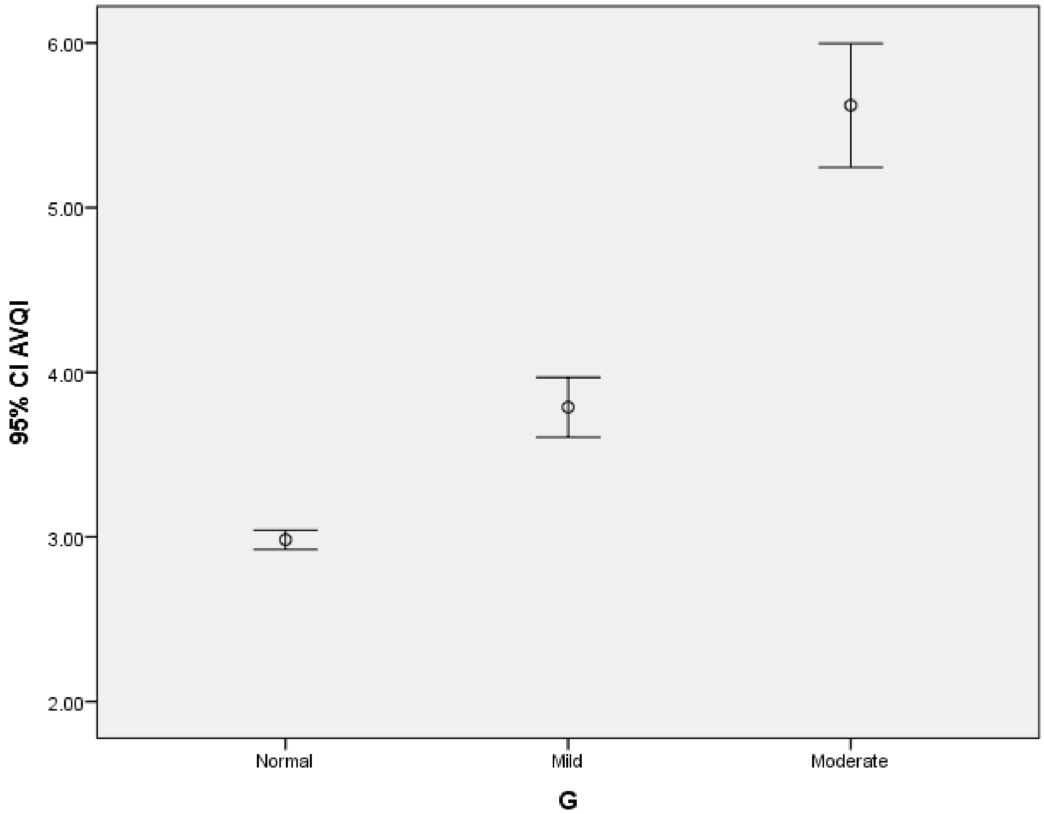

Figure 4.2 Mean and distribution of AVQI across subject groups.

Correlation of AVQI with GRBAS

The obtained AVQI scores and its constituent parameters were correlated with the overall Grade score obtained on GRBAS scale using Spearman's rank order correlation (r_s). The results of correlation of AVQI and its constituent parameters with that of 'G' for the entire subject group are illustrated in the table 4.12. It was revealed that AVQI demonstrated a significantly moderate to good correlation with the 'G' rating of GRBAS.

Table 4.12 Overall correlation of AVQI and its constituent parameters with G rating of GRBAS.

Sl. No.	Parameter	Spearman's correlation coefficient (r_s) with 'G' rating of GRBAS	*p*-value
1.	CPPS	-0.401	0.000*
2.	HNR	-0.279	0.001*
3.	Shim Local	0.257	0.005*
4.	Shim dB	0.290	0.001*
5.	Slope LTAS	-0.366	0.000*
6.	Tilt LTAS	0.162	0.078
7.	AVQI	0.739	0.000*

* Significant at 0.05 level

Further, correlation was also checked for the individuals with normal voice quality and those with dysphonia using spearman's rank order coefficient (r_s). The results of the correlation of AVQI and its constituent parameters with that of 'G' for both the subject groups are depicted in the table 4.13. It was revealed that for normal individuals, AVQI demonstrated a poor to moderately significant correlation with the 'G' of GRBAS (r_s = 0.484, p = 0.000); However, within the dysphonic group, it was observed that, the constituent parameters of CPPS demonstrated a significantly good negative correlation with 'G' (r_s = -0.763, p = 0.000); and Slope of LTAS demonstrated a significant moderate to good negative correlation with 'G' (r_s = -0.711, p = 0.000). AVQI showed a significantly good correlation with 'G' (r_s = 0.867, p = 0.000).

Table 4.13 Correlation of AVQI and its constituent parameters with G for both subject groups.

Sl. No.	**Parameter**	**Normal individuals**		**Individuals with dysphonia**	
		Spearman's correlation coefficient (r_s) with 'G' rating of GRBAS	*p*-value	Spearman's correlation coefficient (r_s) with 'G' rating of GRBAS	*p*-value
1.	CPPS	-0.073	0.469	-0.763	0.000*
2.	HNR	-0.229	0.022*	-0.173	0.465
3.	Shim Local	0.148	0.141	0.243	0.302
4.	Shim dB	0.079	0.436	0.304	0.193
5.	Slope LTAS	-0.048	0.637	-0.711	0.000*
6.	Tilt LTAS	0.087	0.389	0.321	0.168
7.	AVQI	0.484	0.000*	0.867	0.000*

* Significant at 0.05 level

Correlation of constituent parameters of GRBAS with AVQI

The perceptual ratings on the GRBAS scale were correlated with the obtained AVQI scores using Spearman's rank order correlation (r_s). The results of correlation of AVQI with that of 'G' for the entire subject group are illustrated in the table 4.14. It was revealed that AVQI demonstrated a significantly moderate correlation with the perceptual ratings obtained for each of the constituent parameters of GRBAS.

Table 4.14 Overall correlation of parameters of GRBAS with AVQI values.

Sl. No.	**Parameter**	**Spearman's correlation coefficient (r_s) with AVQI**	***p*-value**
1.	Grade	0.739	0.000*
2.	Roughness	0.631	0.000*
3.	Breathiness	0.613	0.000*
4.	Asthenia	0.559	0.000*
5.	Strain	0.606	0.000*

* Significant at 0.05 level

Further, correlation was also checked for the individuals with normal voice quality and those with dysphonia using spearman's rank order coefficient (r_s). The results of the correlation of constituent parameters of GRBAS and AVQI values are depicted in the table 4.15. It was revealed that for normal individuals, the constituent parameters of GRBAS demonstrated a poor to moderate significant correlation with AVQI values except for the parameter of strain (r_s = 0.185, p = 0.066); However, within the dysphonic group, it was observed that, the constituent parameters of Grade, Roughness as well as Breathiness demonstrated a significant good correlation with AVQI scores (p = 0.000); Also the parameters of Asthenia and Strain significantly and moderately correlated with the corresponding AVQI value (p = 0.015).

Table 4.15 Correlation of parameters of GRBAS with AVQI values for both subject groups.

Sl. No.	**Parameter**	**Normal individuals**		**Individuals with dysphonia**	
		Spearman's coefficient (r_s) with AVQI	*p*-value	Spearman's coefficient (r_s) with AVQI	*p*-value
1.	Grade	0.484	0.000*	0.867	0.000*
2.	Roughness	0.269	0.007*	0.755	0.000*
3.	Breathiness	0.212	0.034*	0.776	0.000*
4.	Asthenia	0.204	0.042*	0.535	0.015*
5.	Strain	0.185	0.066	0.534	0.015*

* Significant at 0.05 level

Reference measures for the constituent parameters of AVQI

The reference measures for the constituent parameters of AVQI incorporating for all the gender, language and age effects observed is as tabulated in table 4.16.

Table 4.16 Reference measures for the constituent parameters of AVQI

Sl. No.	**Parameter**	**Gender**		**Language**	
		Male	Female	Malayalam	Kannada
1.	CPPS	13.94 (±1.35)			
2.	HNR	17.00 (±1.94)	19.12 (±1.62)	17.55 (±2.62)	18.24 (±1.88)
				16.52 (±2.21)#	17.48(±1.54)#
				18.56 (±1.37)$	19.67 (±1.69)$
3.	Shim Local	6.45 (±2.07)		6.72 (±1.70)	5.46 (±1.18)
4.	Shim dB	0.68 (±0.12)		0.69 (±0.11)	0.62 (±0.081)
5.	Slope LTAS	-20.21 (±3.81)			
6.	Tilt LTAS	-10.82 (±0.87)			

= Male Values $ = Female Values

Reference measures for AVQI

The reference measures for AVQI values for the Malayalam and Kannada speaking Indian population in the age range of 20-50 years is summarized in the table 4.17 below:

Table 4.17 Reference measures of AVQI for 20-50 year old Malayalam and Kannada speaking population

Parameter	Value
Mean AVQI (SD)	3.03 (±0.32)
Mean ±2SD	2.39-3.67

CHAPTER 5

DISCUSSION

Several researchers hold on to the view that there is not a single objective measure of voice that adequately explains the voice quality as well as the severity of the dysphonia (Yu *et al.*, 2001). Therefore the use of a multiparametric is often recommended. The use of multiparametric approach considers the multidimensional nature of voice and it consolidates the different voice measures to describe the voice quality and dysphonia into a single value. Even though several multiparametric approaches to evaluate the voice quality exists, AVQI devised by Maryn *et al.*, (2010) is a measure that combines both continuous speech as well as sustained vowel in order to assess the voice quality.

This particular study aimed to develop reference data for AVQI and to validate AVQI with perceptual measure (GRBAS scale) for Malayalam and Kannada speaking population. The current study investigated AVQI on 100 normal individuals (50 males and 50 females) and 20 individuals with mild and moderate degrees of dysphonia (10 males and 10 females) within the age range of 20-50 years.

Test-retest reliability of AVQI

The test-retest reliability of AVQI obtained in the present study (Cronbach's $\alpha = 0.973$) was found to be very good. This is in concurrence with the earlier study by Barsties & Maryn (2013) who reported of a low level test-retest variability of AVQI (test-retest procedure outcome value of 0.54). They also reported of no significant differences on AVQI values across two trials of on individuals with voice disorders. A high test-retest reliability value reveals that the type of measure is robust and reliable, which is a prerequisite for the measurement for any type of validity.

Mean, standard deviation of AVQI

The mean value obtained for AVQI for the Indian languages of Kannada and Malayalam in this study is 3.03 (±0.32). This is in concordance with the values reported in the literature for AVQI in other languages for e.g., 2.70 in German (Barsties & Maryn, 2012); 3.25 in English (Maryn, 2014); 3.07 in French (Maryn *et al.,* 2014); 2.80 in Dutch (Barsties & Maryn, 2015); 2.97 in Lithuanian (Uloza *et al.,* 2017); and 3.12 in Japanese (Hosokawa *et al.,* 2017). Thus, the results of this study further add on to the evidence that AVQI is unwavering over different languages across the geographical regions.

Effects of gender, language and age groups on AVQI

There were no significant differences observed on AVQI values across gender groups, language groups and age groups considered in this study. These findings are also in accord with earlier studies by Maryn *et al*. (2010a, 2010b, 2014); Reynolds *et al.,* (2012); Barsties & Maryn, (2012), and Hosokawa *et al.,* (2017).

Maryn, De Bodt, Barsties, & Roy, (2014) compared across English, German, French and Dutch speakers on AVQI and reported of no significant differences across the 4 different language speakers on AVQI values. Along with this, the findings of present study also adds on to the evidence of lack of variation of AVQI with respect to language.

This study utilized 3 sentences in Malayalam and Kannada for the continuous speech sample to derive the AVQI values. However, it is worth noting that the number of syllables within the continuous speech sample used in different languages were lesser than which was selected for this study. Different number of syllables were used by different authors to derive AVQI in different languages (Maryn, De Bodt, & Roy, 2010; Barsties and Maryn, 2012; Reynolds *et al.*, 2012; Kankare *et al.*, 2015; Maryn, Kim & Kim, 2016; and Hosokawa *et al.,* (2017). However, according to Hosokawa *et al.*, (2017), the number of syllables does not cause a significant effect on AVQI value.

There is no published data available for gender difference and age group difference on AVQI values.

Effects of gender, language and age groups on constituent parameters of AVQI

A significant gender effect was observed only for the constituent parameter of HNR (p=0.000) and the other constituent parameters did not show any significant difference across normal and dysphonic individuals. A study by Goy, Fernandes, Pichora-Fuller, & van Lieshout, (2013) revealed that males have lower value of HNR compared to females owing to the physical and structural variations present across the genders. The present study also found that males have a lower HNR value compared to females.

Similarly, HNR, Shimlocal, and ShimdB were found to be significantly different across languages. According to Orlikoff & Kahane (1991), degree of perturbation is inversely associated to the acoustic amplitude of the vowel. Acoustic amplitude can be affected by the amount of nasalance present in the language. Malayalam has a mean nasalance of 21.36% for males 23.16% for females (Devi & Pushpavathi, 2009) whereas Kannada has a mean nasalance of 8.77% for males 14.69% for females (Jayakumar & Pushpavathi, 2005). Given that there is a difference of the nasalance between these two languages, the acoustic amplitude across the languages also vary, which can be thought of bringing about a difference in the perturbation measures of

Shimlocal, and ShimdB. Similarly, the presence of nasal resonance, can dampen the harmonics as well. This could be postulated as a reason for HNR differences across the language groups revealed in the study.

No significant effect was noticed with respect to age groups for the AVQI constituent values in both normal as well as dysphonic population.

Comparison of normal Vs dysphonic population with respect to AVQI

The mean AVQI value obtained for individuals with dysphonia was 4.79 (±0.97). This was higher than the AVQI value obtained for the individuals with normal voice quality. This is supported by the study done by Maryn, De Bodt, & Roy, (2010) which had revealed that AVQI is an exceptional tool in characterizing normal as well as dysphonic voices. Several other studies by Reynolds *et al.,* (2012) Hosokawa *et al.,* (2017) and Uloza *et al.,* (2017) also report of higher values of AVQI in individuals with dysphonia compared to those with normal quality of voice. However, a slight overlap was observed in this study across individuals with dysphonia and those with normal voice quality. This could be attributed to the fact that few subjects meeting the criteria to be within the group of individuals with normal voice quality were found to be having mild dysphonia on both AVQI scores as well as GRBAS scales which would have led to slight overlap in the AVQI values. This has also been reported in a study by Reynolds *et al.,* (2012) wherein there were subjects who were graded as dysphonic on the GRBAS, yet obtained an AVQI score underneath the threshold for voice disorder.

An age group difference was noticed in the individuals with dysphonia with the younger age group obtaining a mean AVQI score of 4.03 (±0.79) whereas the older age group obtained a mean AVQI score of 5.03 (±1.03). This can possibly be due the aging effects on the quality of voice overlying which could be the effect of the vocal pathology. Stathopoulos, Huber, & Sussman, (2011), reported that the acoustic measurements change with advancing age and that there is high variability of acoustic measures in older age groups when compared to that of the younger age groups.

Correlation of AVQI with ‘G’ rating of GRBAS

This particular study revealed that AVQI demonstrated a significantly moderate to good correlation with the ‘G’ rating of GRBAS (r_s = 0.739) for all the three groups. The correlation of AVQI with ‘G’ rating of GRBAS obtained for the subject groups of individuals with normal voice quality was r_s = 0.484 and for those with voice disorders was r_s = 0.867. This finding suggests that AVQI targets the measurement of voice quality and is in congruence with the perceptual rating of voice quality. This is in concordance with several other studies reported in the literature for other languages. In the study by Maryn, De Bodt, Barsties, & Roy, (2014), a correlation of 0.809 in Dutch, 0.868 in English, 0.858 in German and 0.781 in French was found for the AVQI value to that of ‘G’ rating of GRBAS scale. Similarly, a correlation 0.852 was reported by Uloza *et al.* (2017) for Lithuanian, and a correlation of 0.828 was reported by Hosokawa *et al.* (2017) for Japanese language.

In a study by Reynolds *et al.* (2012) on pediatric patients with voice disorders, it was reported that AVQI has a strong concurrent validity as the AVQI values showed a good positive correlation of 0.794 with ‘G’ of GRBAS scale. Similarly, Maryn, Kim & Kim (2016) reported that for sixty individuals with voice disorders, AVQI showed a strong correlation with ‘G’ rating of GRBAS scale with r_s = 0.911. The results of this study are also in similar lines with the above mentioned studies as a strong correlation was observed across ‘G’ rating of GRBAS scale and AVQI in the present study for individuals with voice disorders.

On investigating the correlation of the constituent parameters of AVQI with that of ‘G’ rating of GRBAS scale, it was found that majority of the constituent parameters showed a significant correlation. CPPS showed a fair negative correlation (r_s = -0.401) with ‘G’ rating of GRBAS scale for individuals with normal voice quality and good negative correlation with ‘G’ rating of GRBAS scale for individuals with dysphonia. A typical voice having very much characterized harmonic structure would have a strong cepstral peak as compared to a breathy and hoarse voice where there is an ineffectively characterized harmonic structure (Kumar, Bhat & Prasad, 2010). Thus, it can be suggested that the cepstral peak prominence has a prominent role in determining the quality of voice. The finding of this study with respect to CPPS are in consensus with the findings of Heman-Ackah, Michael, & Goding, (2002) who reported that CPPS for speech showed a significantly good negative correlation (r_s= -0.86) with that of ‘G’ rating of GRBAS scale for individuals with dysphonia; and with that of Brinca, Batista, Tavares, Gonçalves, & Moreno, (2014) who reported that for European Portuguese speakers, a significant moderately negative correlation (r_s = -0.588) for sustained phonation and a low negative correlation (r_s = -0.131) for oral reading exists across ‘G’ rating of GRBAS and CPPS for individuals with normal voice quality and those with dysphonia. Similarly, Jannetts, & Lowit, (2014) studied the voices of hypokinetic and ataxic individuals and studied the correlations of acoustic measures with perceptual measures. It was found that CPPS had a significant good negative correlation (r_s =-0.88) for sustained vowel production and a significantly moderate negative correlation (r_s = -0.53) for reading tasks.

Similarly, in this study, HNR demonstrated a significant low negative correlation (r_s = -0.279) for normal individuals as well as individuals with dysphonia. This finding is in agreement with study by Jesus, Barney, Couto, Vilarinho, & Correia,

(2009) who found that a low negative correlation (r_s = -0.18) exists across HNR and 'G' rating of GRBAS scale. However, this contradicts the findings of, Freitas, Pestana, Almeida, & Ferreira, (2015) whose study revealed that, there was a significantly good negative correlation (r_s = -0.838) across the HNR measurement for sustained vowel in *Praat* to that of 'G' rating of GRBAS scale. However, in the present study, only a low negative correlation was found for HNR 'G' rating of GRBAS scale it can be attributed to the differences in the stimulus used in the study.

ShimLocal as well ShimdB also demonstrated a significantly low positive correlation with 'G' rating of GRBAS scale (r_s = 0.257 & 0.290 respectively). Maryn *et al.* (2010) had earlier reported of moderate positive correlation of r_s = 0.64 and r_s = 0.66 respectively for ShimLocal and ShimdB. The difference can be ascribed to fact that perturbation measures tend to be highly variable and can be affected by methodological or subject related factors. It was reported that, for ShimdB, the test-retest reliability coefficient is 0.55 (moderate) for individuals with normal voice quality and 0.40 (poor) for clinical population (Carding, Steen, Webb, Mackenzie, Deary, & Wilson, 2004).

In this study, a significant low negative correlation was found for SlopeLTAS to that of 'G' rating of GRBAS scale (r_s = -0.366). However, this is contradicting the earlier findings of Maryn et al (2010) wherein it was found that no correlation (r_s = 0.01) exists between Slope of LTAS and 'G' rating of GRBAS scale.

Correlation of constituent parameters of GRBAS with AVQI

The perceptual ratings on the GRBAS scale were correlated with the obtained AVQI scores using Spearman's rank order correlation (r_s) and there was significant moderate to good correlation of all the constituent parameters of GRBAS scale to AVQI. Several studies have been reported in literature wherein moderate to good correlation is present across AVQI and the constituent parameters of GRBAS (Reynolds et al, 2012; Uloza *et al.,* 2017; Hosokawa *et al.,* 2017).

'G' rating of GRBAS scale showed relatively high correlation with the AVQI values as it aims to grade the overall quality of the voice. Following 'G' rating of GRBAS scale (r_s = 0.739), the 'R' rating correlated best with the AVQI value (r_s = 0.631). This could be attributed to the fact that R gives information about the irregularities of the vocal cord vibration (Hirano, 1981) and that the measures of AVQI especially the perturbation measures of ShimdB and ShimLocal tends to measure the glottal variations. Also other glottal parameters such as HNR and cepstral measures would have contributed to this.

Reference measures for the constituent parameters of AVQI

AVQI values demonstrated no gender, language or age group related differences. Likewise, three constituent parameters of AVQI *viz*., CPPS, Slope LTAS, and Tilt LTAS were found to be not affected by gender or language effects as reported in earlier literature. However, perturbation measures of ShimLocal and ShimdB demonstrated differences across languages which can be explained by the high variability of perturbation measures. According to Orlikoff (1995), the perturbation measure of absolute shimmer magnitude is significantly influenced by the mean frequency and intensity of phonation. Such variations in phonation would have led to a variation across the language groups.

The constituent parameter of HNR demonstrated gender as well as language differences in the present study. Goy, Fernandes, Pichora-Fuller, & van Lieshout,

(2013) attempted to devise normative values with respect to age and gender for a large population using several of acoustic measures. They found that, for the normal human voice, several gender related changes existed across the acoustic measures. It was revealed that males obtained a HNR value of 22.9dB whereas females obtained a higher HNR value of 25.3dB. This was attributed to the physical and structural variations present across the structures. The present study is also in agreement with the literature that males have a lower HNR value compared to females.

Wagner & Braun (2003) attempted to investigate the voice quality using several acoustic measures across languages of Polish, Italian and German. Their results revealed that, there was a significant difference across the languages of Polish and Italian (p = 0.002). However, it was also found that, the Polish speakers had highest perturbation measures as well across the languages. Thus, they concluded that there exists no simple direct relation across perturbation measures and HNR. The findings by Wagner & Braun (2003) partially explains the observed language differences in the constituent parameter of HNR in this study.

Thus, the findings of this study put forth that for Indian languages of Malayalam and Kannada, the mean AVQI score is 3.03(±0.32) and that the AVQI value for a normal individual may range between 2.39 to 3.67. Any voice sample for which the AVQI value obtained above this range can be regarded as a dysphonic.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The multifaceted nature of the human voice makes the accurate measurement of its quality a challenging task and the assessment of the human voice quality should be multifaceted as well. As no single objective measure of voice could accurately define the voice quality, multi-parametric assessment of voice was promoted in the late 20^{th} century. From then on, several researchers have tried to converge into an appropriate combination of objective measures to measure dysphonia. Wuyts *et al.,* (2000) developed Dysphonia Severity Index (DSI) which is an objective multiparametric measurement to evaluate the voice quality. It was used by several authors for clinical as well as research purposes. However, due to its limitations owing to reliability and accurate measurement of amplitude related parameters, researchers further sought yet another measure which could describe the voice quality and could account for the limitations of DSI.

Following a series of studies, Maryn *et al.*, (2010) came up with Acoustic Voice Quality Index (AVQI) which made use of concatenated speech sample along with phonation. To prove its usefulness as an objective measure of voice quality, it was necessary to compare it with the "gold standard" for assessing voice quality which is perceptual evaluation. Several researchers tried to validate the AVQI with several perceptual measures such as GRBAS, CAPE-V etc. across several languages and populations all through the world. However, the validation of AVQI was not reported for the Indian population who differ physically, linguistically and culturally from the European as well as East Asian population. Therefore, the present study was taken up to establish reference measures for AVQI and to validate AVQI with the perceptual measure (GRBAS scale) for individuals with normal voice quality and individuals with dysphonia within the Indian context.

The study considered Malayalam and Kannada speakers within the age range of 20 to 50 years. A total of 120 individuals participated in the study of whom 100 individuals had normal quality and 20 individuals had mild to moderate degree of dysphonia. Sustained phonation of /a:/ as well as reading sample were obtained and the corresponding AVQI measures were obtained. The samples were also subjected to perceptual analysis by 5 experienced speech language pathologists. The obtained measures of AVQI and its constituent parameters and the findings of perceptual measures were further subjected to appropriate statistical analysis using SPSS 20.

The results revealed that, there was a very good test-retest reliability of AVQI and its individual parameters. The normative value of AVQI for the Indian Malayalam and Kannada speaking population is 3.03 (±0.32). This value is in agreement with AVQI values reported across the world for several other languages. Effect of gender, language as well age group were not significantly present for the AVQI scores in the present study. However, this was not the case with some of the constituent parameters of AVQI. For e.g., HNR was influenced by gender as well as language, whereas ShimLocal & ShimdB were influenced by language. Other constituent parameters also did not show evident differences across gender, language and age groups.

AVQI was found to have a moderate to good correlation with that of GRBAS scale and there was very good inter-judge as well as intra-judge reliability. Also AVQI scores obtained for individuals with normal voice quality were found to be significantly lower from those obtained for individuals with dysphonia. Also there was a difference in the AVQI scores obtained across the two different severity groups (mild and moderate). Thus, the present study adds on to the literature the reference measures of

AVQI for Indian population and further strengthens the current notion that AVQI is independent of gender, language and age group effects.

Implications of the study

- Present study established reference value for AVQI in Indian population which can be used to differentiate normal from dysphonics.
- The derived normative values for AVQI can be used for diagnostics as well as measuring therapeutic outcomes in clinical setups where access to high cost acoustical analysis measurements are not available.

Limitations of the study

- This study only included those individuals with dysphonia who were having mild or moderate degree of severity in the dysphonic group.
- Within the normal individuals, few of them obtained a rating of Mild dysphonia on GRBAS scale. However, they were retained in the normal group. This would have led to a slight overlap in the scores of AVQI for normal individuals and individuals with mild dysphonia when Mean ± 2SD is considered.

Future directions

- The present study made use of reading sample to elicit the continuous speech from the subjects. However, this might not be feasible for individuals who are illiterates. Therefore future studies can come up with an alternative for the same and validate it.

- The present study reported of the reference measures only for individuals within the age range of 20-50, future studies can investigate the AVQI measures in other age groups such as children as well as geriatric population.
- As the present study investigated two of the Dravidian languages, Malayalam and Kannada, future studies can compare AVQI scores obtained for other non-Dravidian Indian languages.
- This study included only two pathological groups based on severity (mild and moderate), but future studies can include even those with severe degree of dysphonia and compare across different severity groups.
- AVQI measures can be profiled for individuals who are professional voice users such as singers, actors, teachers, theatre artists etc. in the Indian context.

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APPENDIX

Reading Passages in Malayalam and Kannada (Source: Savithri & Jayaram, 2005)

100 Words Passage- Malayalam

ഒരിടത്ത് ഒരു ബ്രാഹ്മണൻ ഉണ്ടായിരുന്നു. അന്ധവിശ്വാസങ്ങൾക്ക് അടിമയായ അയാൾക്ക് ജീവിതത്തിൽ ഒരുപാടു പ്രശ്നങ്ങൾ നേരിടേണ്ടി വന്നു. തടിയനായിരുന്നതിനാൽ ജനങ്ങൾ അവനെ "പൊണ്ണത്തടിയാ" എന്നു വിളിച്ചു. ആര്, എന്ത് വിശേഷാവസരത്തിനു ക്ഷണിച്ചാലും മുൻപേ ഇവൻ ഹാജരാകുമായിരുന്നു.

ഒരു ദിവസം 'ധനപതി'യെന്ന ബാല്യകാലസുഹൃത്ത് ബ്രാഹ്മണനെ തന്റെ മകളുടെ ജന്മദിനാഘോഷത്തിനായി ക്ഷണിച്ചു. എന്നാൽ, സ്നേഹിതന്റെ വീട് ബ്രാഹ്മണന്റെ വീട്ടിൽ നിന്നും ആറു കിലോമീറ്റർ അകലെ ആയിരുന്നു. നടന്നു പോയാൽ ആരോഗ്യത്തിനു നല്ലത്. കൂടാതെ, കൂടുതൽ വിശന്നാൽ ഭക്ഷണം കൂടുതലും കഴിക്കാം. ബ്രാഹ്മണൻ തീരുമാനിച്ചു.

ജന്മദിനാഘോഷത്തിന്റെ ദിവസം എത്തി. ഒരുക്കങ്ങളെല്ലാം വേഗത്തിൽ നടത്തി വീടിനു പുറത്തേയ്ക്കിറങ്ങിയപ്പോൾ ഒരു കുഷ്ഠരോഗി മുൻപിൽ പ്രത്യക്ഷപ്പെട്ടു. ശകുനം ശരിയല്ലെന്നു പറഞ്ഞ് വീട്ടിനുള്ളിലേയ്ക്കുതന്നെ കയറിപ്പോയി. ഇതുപോലെ മൂന്നു പ്രാവശ്യംകൂടി സംഭവിച്ചു. പിന്നീട് അയാൾ വേഗത്തിൽ നടന്ന് സ്നേഹിതന്റെ വീട്ടിലെത്തി. അപ്പോൾ അവിടെ എല്ലാവരും ഭക്ഷണം കഴിച്ച്, താംബൂലം ചവച്ച് വിശ്രമിക്കുകയായിരുന്നു.

വൈകിവന്ന ബ്രാഹ്മണനെ കണ്ട് ധനപതി "എന്തേ ഇത്ര വൈകിയത്? ഭക്ഷണത്തിനുള്ള സമയം കഴിഞ്ഞുപോയല്ലോ", എന്നു പറഞ്ഞുകൊണ്ട് , രണ്ടുവാഴപ്പഴവും പാലും വരുത്തി കൊടുത്തു.

KANNADA PASSAGE

ಬೆಂಗಳೂರು ನಮ್ಮ ರಾಜ್ಯದ ಒಂದು ದೊಡ್ಡ ಊರು. ಈ ಊರನ್ನು ನಮ್ಮ ರಾಜ್ಯದ "ಬೊಂಬಾಯಿ" ಎನ್ನುವರು. ಇಂಡಿಯಾದ ದೊಡ್ಡ ನಗರಗಳಲ್ಲಿ ಇದೂ ಒಂದು. ಈ ಊರನ್ನು ನೋಡಲು ಜನರು ಬೇರೆ ಬೇರೆ ಊರುಗಳಿಂದ ಬರುವರು. ಇದಲ್ಲದೆ ನಮ್ಮ ರಾಜ್ಯದಲ್ಲಿರುವ ಬೇಲೂರು, ಜೋಗ್, ನಂದಿ, ಇವುಗಳನ್ನು ನೋಡಲು ಜನರು ಬರುವರು. ಈ ನಾಡಿನಲ್ಲಿ ರೇಷ್ಮೆಯನ್ನು ಬೆಳೆಯುವರು.

ಕೃಷ್ಣಾ ನದಿಯು ಸಹ್ಯಾದ್ರಿ ಪರ್ವತಗಳಲ್ಲಿ ಮಹಾಬಲೇಶ್ವರದ ಹತ್ತಿರ ಹುಟ್ಟುತ್ತದೆ. ಈ ಪ್ರದೇಶವು ರಮಣೀಯವಾದ ಸ್ಥಾನ. ಇದು ಮಹಾರಾಷ್ಟ್ರ, ಕರ್ನಾಟಕ ಮತ್ತು ಆಂಧ್ರಪ್ರದೇಶಗಳಲ್ಲಿ ಹರಿದು ಬಂಗಾಳ ಕೊಲ್ಲಿಯನ್ನು ಸೇರುತ್ತದೆ. ಇದಕ್ಕೆ ಉಪನದಿಗಳು ಹಲವು. ಕೊಯಿನಾ, ತುಂಗಭದ್ರಾ, ಘಟಪ್ರಭಾ, ಭೀಮಾ, ಮಲಪ್ರಭಾ- ಅವುಗಳಲ್ಲಿ ಕೆಲವು. ಕೊಯಿನಾ ನದಿಗೆ ಅಣೆಕಟ್ಟನ್ನು ಕಟ್ಟಿ ವಿದ್ಯುತ್ತನ್ನು ಉತ್ಪಾದನೆ ಮಾಡುತ್ತಾರೆ.