EFFECT OF DIFFERENT LEVELS OF TRAINING ON SINGING POWER RATIO AND SINGER'S FORMANT IN CLASSICAL CARNATIC SINGERS

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Abstract

This paper presents the two parameters such as Singing power ratio (SPR) and Singer's formant (Fs) for objectively evaluating singing talent/quality among three levels of singers. Thirty singers' (10 junior level, 10 senior level and 10 vidwath level) sung sample of 'Lambodara' song was analysed using LTAS of CSL 4500 software to extract SPR. The sample was sung at three conditions including (1) singing without background music, (2) singing with background music at listening comfortable level and (3) singing with background music at more than listening comfortable level. SPR and presence or absence of F_s was analysed among the singers at three conditions. No interaction between conditions and levels of singing was found for SPR. Fs was not observed at all the three conditions among three levels of singers. There was a gradual increment in the SPR value with the increase in the years of training. Thus, SPR would be an objective tool to measure the singing voice quality in Carnatic singers.

Keywords: Singer's formant, Singing power ratio, Acoustic analysis, Trained singers, Carnatic singers

Introduction

"The human voice is extraordinary. It is capable of conveying not only complex thoughts, but also subtle emotion. In an instant, it can communicate the terror of a scream or the beauty of a song"- explained by Sataloff (2005) about the specialty of human voice. Voice is not only important for human communication but also serves as a primary musical instrument. Anyone who uses their voice in order to carry out their livelihood is considered as professional voice users. One among them is singers and they are referred to as elite vocal performers.

Singing is a unique form of art which frequently requires years of training to

attain the utmost form of performance. Even for the trained ears it is difficult to judge the singing talent. Each singer has a natural, unique and clearly identifiable voice quality that listeners may describe in their own way. For example, one listener may describe a singer's voice as warm voice and the other person may call it matured voice or rich voice. However, all these terms do not quantify or objectively measure the singing voice. With the vastly developing technology, attempts have been made to find which feature of singing voice makes the listener to feel the voice as matured, warmth or rich. Singer's Formant (FS) and Singing Power Ratio (SPR) are among such measures which are used to measure voice quality acoustically (Omori, Kacker, Carroll, Riley and Blaugrund, 1996; and Lundy, Roy, Casiano, Xue and Evans, 2000).

Omori et al., (1996) introduced a parameter called singing power ratio (SPR). They measured SPR by considering the ratio between the greatest harmonic peak between 2 and 4 kHz and the greatest harmonic peak between 0 and 2 kHz. The authors calculated SPR for 37 singers and 20 non singers and concluded that, SPR represented the resonant quality of the singing voice, provided a quantitative measure for evaluating singing voice quality and it has a distinctive correlation with period of voice training. Watts, Barnes-Burroughs, Estis and Blanton (2006) found significant differences in SPR values for voices of untrained talented and non talented singers which suggested the vocal tract resonance and its effect on perceived vocal timbre or quality may be an important variable related to the perception of singing talent.

Kenny and Mitchell (2007) assessed the relationship between acoustic measurement and perceptual judgment in the identification of perceptually preferred voices and comparing the sound quality in voices using and not using the open throat technique. They compared perceptual rankings of vocal quality of expert pedagogues with rankings of acoustic measures (SPR and Energy Ratio) to assess whether these acoustic measurements matched the perceptual judgments of vocal quality. Although they found the expected significant relationship between SPR and ER, there was no relationship between perceptual ratings of vocal samples of singers based on SPR or ER. They concluded that LTAS measures are not consistent with perceptual ratings of vocal quality; such measurements cannot define voice quality and suggested future research with LTAS to address vocal quality by considering alternative measures that are more sensitive to subtle differences in vocal parameters.

Lundy et al., (2000) studied the acoustic analysis of the singing and speaking voice among singing students. Both singing and speaking voice samples were recorded from 55 singing students and analyzed for SPR and standard measures of acoustic analysis. The authors found that SPR values did not differentiate

sung versus spoken samples. The authors did not find any gender difference on SPR and no influence of years of training on SPR.

The singer's formant (FS) is described as an increase in the signal intensity between the third and fourth formants, allowing the singer to be heard without amplification over sounds of accompanying music (Bartholomew, 1934). He stated that a good operatic voice needs a concentration of energy around 3 kHz. He also mentioned that this concentration must be produced with a special resonator in the larynx or lower pharynx. Sundberg (1987) also reported the main acoustical contribution to the generation of the singer's formant which stems from a cluster of third, fourth and fifth formants. Figure 1 illustrates the singer's formant seen as a hump (acoustic peak energy) at around 2-3 kHz region for western singers.

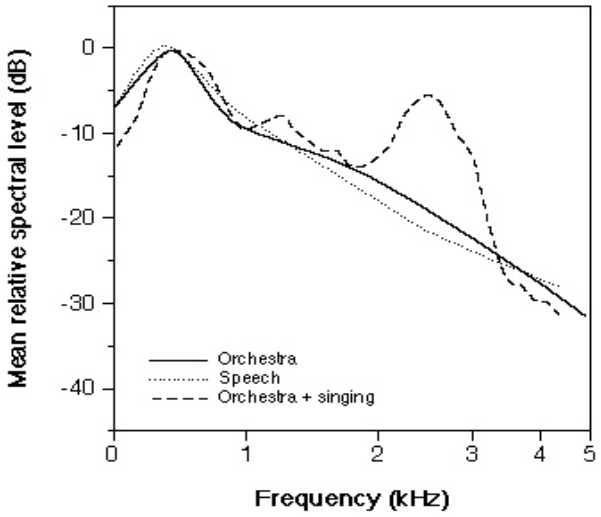


Figure 1: Singer's Formant (FS) (Taken from Sundberg, 1987)

Morris and Wiess (1997) said that the precise location of Fs varies. It might be affected by individual voice types and ranges, the vowels attempted, the pitch and the amplitude produced. All these above mentioned studies have established that FS and SPR are good parameters to judge singing quality in the western context. It is known that Carnatic music is one of the classical systems of music most prevalent in southern part of India that differs from the western music in many aspects. That is, musical progression is in terms of single note i.e. at a given time only one note or its shadow is acting. Thus, it is called homophonic or sometimes just as melodic music. On the other hand

western music is heterophonic or harmonic system as the progression is in harmony and calls for several sounds simultaneously. Hence, there is a need for objective measures like SPR and FS to quantify singing talent in Carnatic singers. Few studies were conducted to see the usefulness of SPR and singer's formant in Indian classical music.

Sujatha (1989) analysed the singing voice of 10 trained (4-10 yrs of training) and 10 untrained singers and found that, most of the trained singers had more energy concentration between the frequencies 2500 to 2969 Hz. Whereas, the energy concentration was more in 2300- 2500 Hz region in untrained singers. Sengupta (1990) studied some aspects of singer's formant (Fs) in North Indian Classical singing. Eight singers (4 males and 4 females) served as the subjects. The author found singer's formant and the centre frequency of Fs increased with raising pitch. The bandwidth was also found to increase with increase in fundamental frequency as like in western singers. Chayadevi (2003) compared Singer's formant between Carnatic music and Hindustani music. The author analysed the sung samples of /a/ vowel in twenty Carnatic and twenty Hindustani vocalists who had minimum 10 years of formal training. The results of the study indicated no significant difference in the parameters measured across two styles of singing except for the bandwidth of Fs which showed significant difference between male singers of two styles of singing. The author observed a shift in the centre frequency of Fs in both the styles of singing. Also, clustering of higher formants was found in the region noted as Fs.

Boominathan (2004) and Mohan (2010) did not find singer's formant in Carnatic classical singers. They justified by explaining that the Indian music is homophonic and accompaniments usually shadow the singer and hence singer would not require projecting his or her voice over an orchestra. This result opposed the earlier studies (Sujatha, 1989; Sengupta, 1990; and Chayadevi, 2003). Mohan (2007) evaluated the usefulness of SPR as an objective measure of singing voice quality in untrained and trained singers, in Indian context. The author considered two groups. Group I consisted of 10 female Carnatic singers who had minimum 6 years of training (mean age: 9.9 years) and group II consisted of 10 female singers who did not receive Carnatic singing training. The participants were asked to sing the Indian national anthem and the sample was analyzed using Vaghmi software. LTAS was extracted on the sung sample and SPR was measured. The author did not find any significant difference between the two groups on SPR. The author concluded that SPR may not be helpful in evaluating the progress of a

singer's training towards the development of a perceptually rich vocal quality in Carnatic singing.

Sujatha (1989), Sengupta (1990) and Chayadevi (2003) reported the presence of singer's formant, whereas studies by Boominathan (2004) and Mohan (2010) reported the absence of it. These studies reported contradictory results and far from conclusive about the singer's formant in Carnatic singers. The present study made an attempt to simulate the heterophonic condition and calls for accompanying music simultaneously like western music and tried to address the effect of this background music at different levels on SPR and Fs across different levels of trained singers.

Aim of The Study

The aims of the study were two-folded:

1. To investigate the effect of different levels of training on singing power ratio (SPR) and singer's formant.
2. To determine the effect of background music on singing power ratio (SPR) and singer's formant across different levels of singers.

Method

Participants: Thirty singers (7 males and 23 females) participated in this study. They were further divided into three groups based on the levels of training in Carnatic music. Group I consisted of 10 junior grade Carnatic classical singers (5 males and 5 females) within the age range of 9-12 years, who had at least 3 years of training. Ten senior grade singers (1 male and 9 females) constituted group II, who were within the age range of 12-21 years, having minimum 6 years of training. Group III consisted of 10 singers of vidwath level (1 male and 9 females) within the age range of 20-35 years, who had minimum 15 years of training. All the participants had normal speech, language, hearing and communication skills and free from any upper respiratory infections at the time of the study.

Procedure: Participants were explained about the purpose of the study and written consent was taken from them. The stimuli consisted of song of Carnatic music i.e. Pillari Geethe Lambodara of Malahari raga and Roopaka tala (Raga is the mode or melodic formulae and tala is the rhythmic cycles). All the participants were seated comfortably in a noise free room. The song 'Lambodara...' was played to the participants through the Intel head phones to familiarize them with the song. Singers were given trials to rehearse the song

along with the background music (maximum number of trials being 3) before recording. The participants were instructed to sing the song 'Lambodara...' in their best singing voice, assuming that they were singing in a concert with the listeners seated at a distance of 20 feet. Recording was done in three different conditions. That is, the participants were asked to sing the song 'Lambodara...' without background music (Condition 1), sing along with background music (Condition 2) at their comfortable listening loudness level, and sing along with background music played at slightly higher than their comfortable loudness level (Condition 3). Background music was extracted from Karaoke software and played to participants through headphones (at ear level) for condition 2 and 3. Olympus (WUS-550M) digital voice recorder was used for recording the singing sample at a sampling rate of 44.1 kHz. A distance of 8 to 10 cm was maintained between the voice recorder and mouth of the participants.

Analysis: The recorded samples were transferred to the computer and down sampled to 8 kHz using Adobe Audition 1.0 software. The second stanza of the song was considered for the acoustic analysis. Computerised Speech Lab (CSL 4500 model) from KayPENTAX, New Jersy, USA was used for the purpose. The duration of the selected sample was 16 seconds. SPR was extracted from Long Term Spectrum Analysis (LTAS) using Hamming window. Energy peaks between 0-2 kHz and 2-4 kHz were measured from LTAS and SPR was calculated by subtracting the amplitude of the strongest peak between 2-4 kHz from 0-2 kHz. Singer's formant was evaluated through visual inspection of acoustic spectrum by considering a boost of energy peak between 2-4 kHz. Presence or absence of the singer's formant was noted across three groups of singers and across three conditions. The data obtained were compared between different levels of singers and across conditions and further, subjected to statistical analysis using SPSS 17 software.

Results

The results of the study are discussed under three sub headings; (i) SPR, (ii) Fs and (iii) Level of background music.

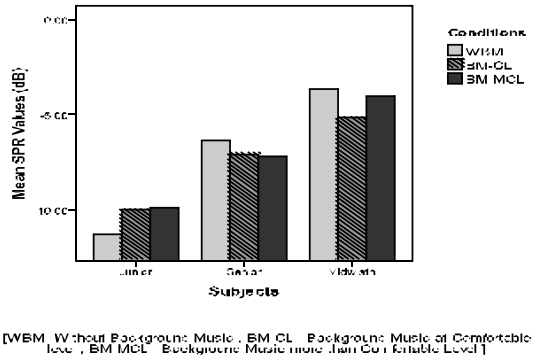
i) **Singing Power Ratio (SPR):** The mean and standard deviation of SPR was calculated for the three groups of singers using descriptive statistics. Table 1 shows the mean and standard deviation of SPR values for three groups of singers across different conditions.

Table 1: Mean and S.D for SPR values in dB for three different conditions

Conditions	**Condition 1** (WBM)	**Condition 2** (BM-CL)	**Condition 3** (BM-MCL)
	Mean (S.D)	**Mean (S.D)**	**Mean (S.D)**
Group I (Junior)	-11.28 (2.90)	-10.00(2.52)	-9.87(3.44)
Group II (Senior)	-6.34 (3.08)	-7.10(2.10)	-7.17 (2.92)
Group III (Vidwath)	-3.67(2.39)	-5.17 (2.68)	-4.06(2.22)

[WBM Without background music , BM CL Background Music at Comfortable level , BM-MCL-Background Music more than comfortable level]

The mean SPR score was least for junior grade singers and highest for vidwath grade singers in all three conditions. The overall mean SPR across three conditions didn't show much difference. Figure 2 illustrates the mean SPR values for three groups of singers across three conditions.



[WBM Without Background Music , BM CL Background Music at Comfortable level , BM MCL Background Music more than Comfortable Level]

Figure 2: Mean SPR for three groups of singers across three different conditions.

Mixed ANOVA was done for conditions as within subject variable and grade as between subject factor which revealed no statistically significant difference across the conditions and no interaction between conditions and grade. But, grade wise significant differences was noticed ($F(2, 27) = 20.33$, $p<0.001$). To determine the grade wise significant difference, Duncan's post hoc test was administered. Duncan's post-hoc results showed that the three grades of singers were different from each other in condition 1. Table 2 shows the results of Duncan's test for condition 1. That is, the three levels of singers (junior, senior and vidwath) are different from each other on SPR in condition 1 (without background music).

Table 2: Duncan's test result for condition 1

Groups	N	Sub-set		
		1	2	3
Group I	10	+		
Group II	10		+	
Group III	10			+

('+' in different column indicate statistical significant difference between the groups)

Table 3: Duncan's test result for condition 2

Groups	N	Sub-set	
		1	2
Group I	10	+	
Group II	10		+
Group III	10		+

('+' in different column indicate statistical significant difference between the groups and '+' in same column indicate no statistical difference)

Table 4: Duncan's test result for condition 3

Groups	N	Sub-set		
		1	2	3
Group I	10	+		
Group II	10		+	
Group III	10			+

('+' in different column indicate statistical significant difference between the groups)

Table 3 shows the results of Duncan's test for condition 2. That is, junior level singers are significantly different from other two (senior and vidwath) group of singers on SPR and among senior and vidwath, there is no significant difference found in condition 2 (background music at comfortable level). Table 4 shows the results of Duncan's test for condition 3. That is, the three levels of singers (junior, senior and vidwath) are different from each other on SPR in condition 3 (background music more than comfortable level).

(i) Singer's Formant: On visual inspection, singer's formant was not prominent in all three conditions in all the three groups. There was an overall increase in the amplitude of the acoustic spectrum when the

loudness of the background music was increased but no effect on singer's formant was found.

(ii) **Level of background music**: It can be inferred from figure 2 that the SPR value decreased from condition 1 to condition 3 in junior level singers. The SPR value increased from condition 1 to condition 3 in senior level singers and as such clear trend was not noticed in vidwath grade singers.

Discussion

In classical singing training one of the fundamental goals would be developing good singing voice quality by improving the resonance. An objective tool to quantify this quality which can be used as a tool to measure the progress would be of great use. This study compared the SPR, which represents the rich resonant quality of singing voice, across 3 levels of Carnatic vocalists. There was a gradual increase in the SPR values as the number of years of training increased. This clear trend represents a training effect in the development of good singing voice. The results are in agreement with the study done by Omori et al., (1990) who found that SPR of sung /a/ was significantly greater in singers when compared to non- singers. The results of this study is not in consonance with previous investigation done by Mohan (2007) who reported no significant difference between trained versus non-trained singers on SPR values. The difference in the findings can be attributed to the difference in the methodology, study population, song employed, years of training in Carnatic music and instrumentation variations.

SPR was different in all the three levels of singers in condition 1 and condition 3. In condition 2, the group II singers (seniors) performed similarly as group III (vidwath singers). That is, SPR value differentiates three levels of singers without background music (condition 1) and background music more than comfortable level (condition 3). In condition 2, junior singers are different from other two levels of singers and there is no significant difference between senior and vidwath singers based on SPR values. The obtained result is beyond the assumptions of the present study and the reason behind this remains unsolved.

The other parameter investigated in this study was singer's formant across three different conditions to simulate a condition which is similar to western context where the singers sung in presence of loud background accompaniment. Through visual investigation, it was found that singer's formant was not prominent even in condition 2 and 3 as expected. The results are not in agreement with the earlier findings of Chayadevi (2003), Sengupta (1990) and Sujatha (1989) who reported presence of singer's formant and

support the findings of Boominathan (2004) and Mohan (2010) who reported absence of singer's formant. It can be attributed to the fact that the Carnatic vocalists are not trained/learnt to sing unlike western singers against loud accompaniment, as Carnatic music is melodious and homophonic.

Overall, there was increase in the amplitude of the spectrum when the loudness of the background music was increased. That is, there was increase in the amplitude of the spectrum in both 0-2 kHz range as well as in 2-4 kHz range. This overall increase in the spectral amplitude would be because of Lombard effect.

Conclusions

Vidwath level singers (group III) had the highest SPR values when compared to senior level singers. Also, junior level singers (group I) had the least SPR values among the other two groups. This indicates, longer the training, higher the SPR value. Higher SPR value in all the three conditions in vidwath group reflected greater energy in the region of 2-4 kHz. It further hints that vidwath singers are indeed able to manipulate the vocal tract to tune the voice spectrum for the production of a target voice quality. This process in training needs to be gradually achieved by juniors and senior singers during the course of training. Hence, SPR would be considered as an objective tool for monitoring the training progress and measure the singing talent. Also, SPR analysis can be consider in the routine clinical voice evaluation for singers.

Under condition 1, 2 and 3, singer's formant was not prominent in Carnatic vocalists. Even in presence of loud background music (condition 3), the trained singers' physiological system does not adapt to improve the resonance at higher frequencies unlike western singers. Generalization of the results of the present study should be made with caution because of small sample size. To conclude, the study has found a gradual increase in SPR measure from junior level to vidwath level of training. Also, the background music has invariable effect on SPR value among the singers which need to be addressed. More number of singers and vocalic portion of the sung sample can be considered in future studies in the similar line.

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