

VOWEL IDENTITY AND INTELLIGIBILITY AT THREE DIFFERENT PITCH LEVELS IN INDIAN CLASSICAL SINGING

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Abstract

Singing is ubiquitous in human society, and it is unique among music performance as being the only form to combine music with language. Intelligibility is an important aspect of communication during singing performance. Listener, Environment, Music and pitch are related factors that have been reported to affect the perception of song. Present study was aimed to determine differences in vowel identification and intelligibility scores obtained for speech and singing samples sung across different pitches of Hindustani and Carnatic singers. The target words were recorded in speaking and singing (low, mid and high pitches) conditions, followed by preparation of target stimuli. Twenty Speech Language Pathologists carried out identification task and intelligibility rating of the vowels and the scores were subjected to statistical analysis. The findings from the study indicated that in vowel identification task, the listeners did not show much difference in identifying vowels sung by two groups (Hindustani and Carnatic). On perceptual analysis of intelligibility of these vowels sung and spoken, all the spoken vowels obtained rating of good in both groups whereas the intelligibility was rated as poor for sung vowels especially at high and low pitches which could be due to the elevated laryngeal level and depression of the larynx during high and low pitches. Overall Vowel identification scores were poor for Carnatic singers when compared to Hindustani singers. This difference could be attributed to the use of different vocal tract configuration for their respective style of singing and rhythmical pattern.

Key words: Singing, Vowel Identification, Carnatic, Hindustani

Singing is ubiquitous in human society, and it is unique among music performance as being the only form to combine music with language. Much has been written on music's similarities to and differences from language (Meyer 1956, Sloboda 2005), but communicating the sung text is clearly much more similar to language communication than mere musical expressivity. Many people attending concerts sung readily state that they are unable to understand the words being sung, suggesting for a closer look at the intelligibility of sung voice. Speech intelligibility can be defined as the "degree of clarity with which one's utterances are understood by the average listener" (Nicolosi, Harryman, & Kresheck, 1989). Connolly (1986) stated that "among the factors necessary for successful oral communication, intelligibility is clearly one of the most fundamental".

One of the main factors underlying the singer's ability to sing in such a way that 'the text is intelligible to the listener', is the singer's vocal technique (Falkner, 1994 & Adams, 1998). Vocal pedagogy emphasizes smoothness of tone, dynamic and pitch range, and power, considering the voice as another musical instrument, but also stressing the importance of diction. This underlies communication, arguably the singer's foremost responsibility, whatever language the singer is using. Furthermore, environmental

factors such as acoustic and within music variables such as clarity of word setting can also affect intelligibility. The musician's focus, then, is the performer's ability to convey the sense of the words he or she is singing and the influence of the environment and the music.

One of the potential goals of song communication is for listeners to gain some level of understanding of the message being communicated. In a language with which the listener is familiar, this involves understanding the individual words, and therefore the intelligibility of those words is of paramount importance. This raises two questions: How intelligible are sung lyrics? And what are the causes of the loss of intelligibility? Existing research has already shown that listeners have significant difficulty in discriminating different sung vowels. This is especially apparent for tones with relatively high fundamental frequencies as might be sung by a soprano. Other factors affecting the intelligibility includes articulation, diction, enunciation, breathing and phrasing, communicating text, expression, stage presence; voice quality and range; listener-related eleven factors including attention; desire to understand words; familiarity with language; hearing ability, environment-related thirteen factors including distraction; access to text; visibility of singer(s); acoustic and music- and

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words-related seven factors including genre; relationship between music and words; repetition etc.

During speech, vowel targets are reached only briefly and are influenced by co-articulation. During singing, however, the vowel must be prolonged according to the rhythmic duration of the word, prescribed by the composer. Hence, the ability to hold a relatively constant vocal tract configuration must become highly developed in the singer. Additionally, which vowel configuration is chosen, and which vowel is perceived by the listener, will determine the conveyance of the meaning of the word. If the vowel sound is inaccurate, so might be the received meaning.

The study of vowel intelligibility during singing has a rather rich history. Typically, as the fundamental frequency rises during singing by women, the first formant will begin to rise ahead of the fundamental frequency to preserve beauty and loudness but not preserve vowel intelligibility. (John & Pierre, 1962, Howard & William, 1968 Sundberg, 1999; Harry, Ana & Kenneth, 2000) The typical finding is that higher sung frequencies tend to have lower vowel intelligibility. (Morozov, 1964; Titze, 1982; William, 1967; Nicole, 1985; Martha & Charles, 1990).

Smith and Scott (1980), for example, studied the intelligibility of vowels produced by a trained soprano in operatic conditions. Ten listeners were asked to discriminate four similar English vowels produced at different pitch levels. Smith and Scott found that the intelligibility of isolated vowels for pitches above F5 was reduced by 50% compared with the same vowels sung at C#5. That is, they demonstrated a dramatic reduction in intelligibility for high sung vowels. When sung with a raised larynx (as might be done in popular music styles) the intelligibility between C#5 and F5 dropped only 10 percent, but then dropped more dramatically as the pitch height increased. Benolken and Swanson (1990) carried out a similar experiment with a trained operatic soprano student. The soprano produced twelve different vowels (both sung and spoken). Twenty-eight phonetically untrained listeners were asked to judge the isolated vowels by comparing them to target words. The results of Benolken and Swanson replicated the earlier work of Smith and Scott: American English sung vowels become increasingly difficult to discriminate as the fundamental frequency is increased.

Hollien, Mendes-Schwartz and Nielsen (2000) also carried out an intelligibility study of sung vowels. They employed eighteen professionally

trained male and female singers. Each singer recorded three isolated vowels at two pitch levels and two loudness levels. Listeners included voice teachers, phoneticians, speech pathology students and untrained undergraduate students. In total, some fifty listeners were asked to identify the vowel and also identify the sex of the singer, he found that few vowels are correctly identified when the fundamental frequency reaches or exceeds the typical first formant. In general, incorrectly identified vowels tend to be confused with central vowels. Burleson (1992) speculated that apart from the difficulties involved in discriminating vowels, other aspects of phonology might be expected to contribute to problems in intelligibility rhythmic aspects of prosody, such as word stress, might also be disrupted by musical settings. However, Burleson did not produce an empirical demonstration of such disruptions.

The work of Smith and Scott (1980), Benolken and Swanson (1990), and Hollien, et al. (2000) has admirably demonstrated the problem of fundamental frequency on the intelligibility of vowels. While vowel discrimination is a very important aspect of language perception, there are many other elements that contribute to language intelligibility.

From the singer's point of view, communicating text is only one aspect of their performance, but it is arguably one of the most important. Singing training encompasses many technical aspects, including both vocal technique and diction, with the emphasis on the latter being on developing clarity of diction (Falkner, 1983 & Adams, 1998). The literature suggested that the low pitch sung vowels would be identified more often, and there would be a larger proportion of correct identifications when sung by the male singers. Various articles attempt to define the role played by pitch, intensity, rate of production, and vibrato in the comprehension of vowels and consonants (Husson, 1957, 1958; Cornut and Lafon, 1960; Howie and Delattre, 1962; Scotto, 1972, 1978, 1981; Germain & Seassau, 1982). Here we limit our study to the influence of pitch on the intelligibility of sung vowels in singing.

Most popular forms of music involve the human voice. In nearly all cultures, singing is one of the preeminent forms of music making. In the present study the question was whether there was recognition of sung lyrics. In other words, how well the listeners identify the intended sung vowels or how intelligible will be the vowel sound perceived during singing. It was found that no attempts were made in Indian classical singing to study the vowel identification scores, which contributes to the need for present study.

Thus the present study was carried out to look at Vowel intelligibility achieved by Indian classical singers of two different styles.

Objectives of the study

1. To compare the vowel intelligibility of spoken and sung vowels between two groups of Indian classical singers (Hindustani and Carnatic)
2. To compare the spoken and sung vowel intelligibility across different pitches in two groups of Indian classical singers (Hindustani and Carnatic).

Method

The study was carried out in the following steps;

Step 1-Development of target words

Three cardiac /a/ /i/ and /u/ vowels which are present in Hindi and Kannada were considered for the present study. Lists of words having a mean length of three syllables were prepared in Kannada and Hindi language which contained the 3 target vowels. The stimulus items in the task were subjected to familiarity check by 5 native speakers of the both languages using a 3 point rating scale (not familiar, familiar and very familiar) in class room teaching. Those items which were rated as not familiar were excluded and a final list of 18 items were made in both languages.

Step 2- Recording of the target words

Participants

Eight trained classical singers were recruited to generate the experimental stimuli. This consisted of four Hindustani singers whose mother-tongue was Hindi (2 males and 2 female singers) and the other group consisted four Carnatic singers whose mother-tongue was Kannada (2 male and 2 female singers). All singers had 10-12 years of singing training and reported they still pursue singing as their profession.

Instrumentation and recording procedure

A microphone SSD-HP 202 dynamic stereo mic 105 dB/mV was mounted on a stand, the height of which was adjusted for each singer

participant, the mic was connected to a PC for recording. A Master Key Chromatic Pitch Instrument (Wm. Kratt Co. A-440) was used for giving the predetermined pitches to the subjects. Stimuli were recorded in a 200-seat auditorium/recital hall, the recordings made in these circumstances considered to be similar in reverberation and ambience to standard recital recordings.

Each of the singers was requested to perform the following tasks in their respective language.

Task I: Speaking

In the first task, singers were asked to say the word list in the same manner as how they naturally speak. They were instructed to speak in the same way as they might normally speak and not attempt to enunciate the words more clearly or less clearly than you would in normal theatrical declamation.

Task II: Singing

Each subject sang the list of 18 words in the order in which they were assigned and in their respective style of singing. Each word was sung in 3 different pitches low, mid, and high with reference to singing range of pitch without reaching the falsetto. Each singer stood approximately eleven inches from the microphone with no attempt being made to control head position during the recording. Singers were instructed to sing them as you might normally sing and not attempt to enunciate the words more clearly or less clearly than you would in your ordinary singing. A practice trial was given before recording for all the singers.

Step-3 Preparation of target stimuli for testing intelligibility

The words were analyzed for vowel duration and vowels more than 500ms were considered to prepare the tokens. The vowel portions were extracted from the recorded words using PRAAT software version 5.0.47. Each isolated vowel ranged 400 to 500 ms in duration. A total of 192 vowel stimuli were extracted out of which 96 from Kannada vowels and 96 were Hindi.

Table 1: *The details of the number of tokens used at low, mid and high pitch for vowel /a/, /i/, and /u/.*

Task	HINDUSTANI SINGERS								CARNATIC SINGERS							
	LP		MP		HP		SPK		LP		MP		HP		SPK	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
/a/	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
/i/	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
/u/	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

The 96 Kannada vowels stimuli were randomized and two tracks were prepared which contained 48 vowels in random order with a gap of 8 seconds between the vowels, similar tracks were prepared in Hindi also. Finally a total of 4 tracks were prepared for perceptual analysis in 2 different languages.

Step-4 Perceptual Analysis

Judges: Total of 20 speech language pathologists (who are undergoing post graduation training) analyzed the vowel samples. These subjects formed two groups 10 native speakers of Hindi (analyzed Hindustani) and other 10 were native speakers of Kannada (analyzed Carnatic).

Procedure: Each judge was seated comfortably in a free field listening situation. Listening tapes were presented through Speakers. They were asked to identify the vowels and transcribe it on the response sheet and were asked to rate on a

three point rating scale (poor, acceptable and good) for intelligibility of each vowel.

Statistical analysis: The data obtained for identification tasks for both groups were tabulated. Descriptive analysis was carried out for the obtained data. The mean and standard deviation was calculated for both groups using SPSS version 10 Statistical analysis software. Percentage was calculated for intelligibility scores

Results

The present study aimed at determining the vowel intelligibility achieved at three different pitches by Hindustani and Carnatic singers. The identification scores and the intelligibility rating obtained from 10 Hindi and 10 Kannada judges were subjected to statistical analysis. The mean scores obtained from the listeners for identification scores is given in the table below.

Table2(a): *The mean identification scores obtained for two groups.*

		Hindustani				Carnatic			
		LP	MP	HP	SPK	LP	MP	HP	SPK
/a/: F	Mean	3.4	3.4	3.0	3.8	3.4	3.6	3.4	4.0
/i/: F	Mean	3.6	3.4	3.0	3.8	3.0	3.6	3.4	3.8
/u/: F	Mean	2.4	3.4	2.0	3.6	2.2	2.8	2.2	3.4
/a/: M	Mean	3.4	3.8	3.0	3.8	3.0	3.6	3.0	4.0
/i/: M	Mean	3.2	3.6	3.0	3.6	2.8	3.6	2.6	3.8
/u/: M	Mean	3.4	3.6	1.8	4.0	2.6	3.6	2.2	3.8

Table2 (b): *The standard deviation obtained for two groups.*

		Hindustani				Carnatic			
		LP	MP	HP	SPK	LP	MP	HP	SPK
/a/: F	SD	0.51	0.51	1.15	0.42	0.84	0.51	0.84	0.00
/i/: F	SD	0.84	0.51	0.66	0.42	0.66	0.51	0.84	0.42
/u/: F	SD	0.84	0.84	0.94	0.51	1.22	1.03	1.22	0.51
/a/: M	SD	0.51	0.42	0.66	0.42	1.22	0.51	0.94	0.00
/i/: M	SD	1.22	0.84	0.94	0.51	1.22	0.51	0.51	0.42
/u/: M	SD	0.84	0.51	1.22	0.00	0.51	0.51	0.78	0.42

Identification scores obtained from listeners who judged the vowels sung by Hindustani singers showed that the mean identification scores were 3 and greater for the vowel /a/ in all the pitches which is observed for both males and females. The vowel /i/ sung by female and male Hindustani singers had mean identification scores of 3 and greater. The vowel /u/ sung by female Hindustani singers at low and high pitch obtained mean identification scores of 2.4 and 2, whereas the scores of 3 and above in mid and speaking conditions, whereas for male Hindustani singing sample a score of 1.8 was obtained for high pitch and a score of above 3 was obtained for low, mid and speaking conditions.

Identification scores obtained from listeners who judged the vowels sung by Carnatic singers showed that the mean identification scores were 3 and greater for the vowel /a/ in all the pitches which is observed for both males and females. The vowel /i/ sung by female Carnatic singers had mean identification scores of 3 and greater, whereas male Carnatic singers obtained a mean identification scoring of less than 3 in low and high pitches. For the vowel /u/ sung by female Carnatic singers the mean identification scores were poor (below 3) except in speaking condition, whereas for vowel /u/ sung by male Carnatic singers, 3 and above scores was obtained at mid and speaking conditions whereas

poor scores obtained at both low and high pitch conditions (<2).

The intelligibility ratings which were obtained based on three point rating scale [Poor (P), Good

(G) and Average (A)] was converted into percentage. The percentage scores which were obtained for Hindustani and Carnatic singers are given in table 3 and 4 respectively.

Table 3: *The intelligibility scores obtained for female and male Hindustani singers.*

		FEMALE				MALE			
		LOW (%)	MID (%)	HIGH (%)	SPK (%)	LOW (%)	MID (%)	HIGH (%)	SPK (%)
/a/	P	25	10	70	0	10	—	55	10
	A	25	50	25	15	40	35	40	30
	G	50	40	5	85	50	65	5	60
/i/	P	30	25	75	0	45	—	55	10
	A	35	40	5	10	50	55	35	20
	G	35	35	20	90	5	35	10	70
/u/	P	25	—	80	5	40	15	85	15
	A	45	60	15	20	30	30	10	10
	G	30	40	5	75	30	55	5	75

Careful observations of the above table show that all the vowels had good intelligibility rating in the speaking condition. The vowel /a/ sung by the Hindustani singers was rated as ‘poor’, ‘Acceptable’ and ‘Good’. The vowel /a/ sung by the female Hindustani singers were rated as poor in 70% high pitch condition and 50% of the vowel /a/ sung by both male and female singers at low pitch was rated as good, whereas only 5% of the vowel /a/ sung at the high pitch by the male Hindustani singers were rated poor. 65% of the vowels /a/ sung at the mid-pitch was rated as good.

For the vowel /i/, 75% of the female high pitched listening stimulus, as well as 55% of male highpitched stimulus were rated poor. 80% of the vowel /u/ at high pitch sung by females were rated as poor, where as 85% were rated as poor when sung by the male singers. When vowel /u/ was sung at mid pitch 60% scores were rated as acceptable by the judges and when male sung /u/ at mid pitch 55 were rated as good. When male and female singers sung at low pitch, scores of 40%, 30% and 30% (for male) was good and 25%, 45% and 30% (for female) was rated as poor, acceptable, and good respectively.

Table 4: *The intelligibility rating obtained in percentage for Carnatic singers.*

		FEMALE				MALE			
		LOW (%)	MID (%)	HIGH (%)	SPK (%)	LOW (%)	MID (%)	HIGH (%)	SPK (%)
/a/	P	35	15	25	15	20	15	40	10
	A	35	40	55	15	50	25	40	10
	G	30	45	20	70	30	60	20	80
/i/	P	60	10	20	10	70	15	35	5
	A	25	60	60	20	20	40	55	5
	G	15	30	20	70	10	45	10	90
/u/	P	60	40	65	5	55	30	70	5
	A	25	20	20	5	25	55	20	10
	G	15	40	15	90	20	15	10	85

The above tabulated values shows the intelligibility rating rated for low, high, mid, and speaking condition by various listening judges. The vowel /a/, /i/ and /u/ were rated as good in speaking condition. The vowel /a/ when sung by female Carnatic singers was judged 55% of time as acceptable. Rating of good was assigned 45% time when sung by female and 60% when sung by male Carnatic singers. 35%, 35%, 30% and 20%, 50%, 30% was rated as poor, acceptable and good when sung by female and male singers at low pitch respectively.

For the vowel /i/ sung by the male Carnatic singer was rated as poor when sung at low pitch and 60 % was rated as acceptable at mid and high pitch. For male Carnatic singers 70% of time the rating was poor at low pitch and 45% was rated good at mid pitch and 55% was rated acceptable at high pitch condition. For the vowel /u/ sung by the female Carnatic singers was rated 65% of times poor at high pitch condition, but when sung at low pitch was rated as poor (60%). When male Carnatic singers sung vowel /u/ at low pitch, 55% of time was rated as poor and when sung at mid pitch 55% of time was rated acceptable. But at high pitch 70% was rated as poor.

Discussion

The present study aimed to compare the sung vowel intelligibility across different pitches in two groups of Indian classical singers (Hindustani and Carnatic) and also to compare the vowel intelligibility of sung vowels between two groups of Indian classical singers (Hindustani and Carnatic). Three cardinal vowels /a/ /i/ and /u/ which are present in Hindi and Kannada were considered for the present study, a total of four Hindustani singers (2 Male and 2 Female) and four Carnatic singers (2 Male and 2 Female) were made to sing and speak words consisting of target vowels to generate the stimuli. The vowels extracted from the sung and spoken words were used as stimuli. The results obtained for identification and intelligibility of vowels sung by two groups of singers is described in the previous section.

For identification task of vowel /a/ at different pitches of sung samples, good scores were obtained for males and females of both groups (mean range from 3.2 to 4). These results indicated that the identification scores did not differ across pitches and between samples of males and females singers of both groups. The vowel /i/ sung by female and male Hindustani singers and female Carnatic singers had mean identification scores of 3 and above, whereas male Carnatic singer's samples obtained a mean identification score of less than 3 in low and high pitches. The identification scores for vowel /u/ was reduced compared to the other two vowels, identification scores of vowels sung by female singers of both the groups were poor in high and mid pitches, where as in males Hindustani singers obtained poor score for vowel /u/ only in high pitch, whereas samples of Carnatic male singers obtained poor scores at low and mid pitch.

To assess the intelligibility of vowels, three point rating scale (Poor, Acceptable and Good) was provided for the judges and responses were scored in percentage. The results for intelligibility ratings for Hindustani singers indicated that, at high pitch all the vowels were judged as poor (range 55 to 85%) and only 5% was rated as good in both males and females. The intelligibility of all the vowels at low and mid pitches was rated either as acceptable (range 30 to 65%) or good (range 30 to 60%). Overall the results showed that intelligibility was good for speaking condition compared to singing. In singing, high pitch vowels were mostly rated as unintelligible compared to mid and low pitches in both males and females.

The intelligibility scores obtained for Carnatic singers for the vowel /a/ in three conditions of

singing was scored as acceptable (range 35-40%) and poor (15 to 40%) for both males and females. Vowel /i/ sung by both males and females at low pitch were rated as poor (60 to 70%), the same vowel sung at mid pitch was judged as acceptable (40 to 60%) and good (30-45%) whereas for high pitch for both males and females it was rated as acceptable (55 to 60%) and poor (20 to 35%). Vowel /u/ was judged as poor mostly in all singing condition (40-70%), these results indicated overall poor intelligibility scoring for sung vowels compared to speaking condition. This may be due to the elevated laryngeal level and depression of the larynx during high and low pitches respectively. These changes may affect the vocal tract configurations which in turn affects the vowel formant patterns.

Benolken and Swanson (1990) carried out a similar experiment with trained singers who produced twelve different vowels (both sung and spoken). The results showed that the American English sung vowels become increasingly difficult to discriminate as the fundamental frequency is increased. Smith and Scott (1980) studied the intelligibility of vowels produced by trained singers. That is, they demonstrated a dramatic reduction in intelligibility for high sung vowels.

The overall findings from the study imply that in vowel identification task, the listeners did not show much difference in identifying vowels sung by two groups (Hindustani and Carnatic). Identification scores obtained for both the groups showed good scores for the vowels /a/ and /i/ in different singing conditions except the scores obtained for female singers of both the groups for the vowel /u/.

On perceptual analysis of intelligibility of these vowels sung and spoken, not surprisingly all the spoken vowels obtained rating of good in both groups. In Hindustani singers for both males and females at high pitch, most of the vowels were judged as poor whereas mid and low pitch vowels were judged as acceptable. In Carnatic singers all the sung vowels were rated as poor and acceptable. This suggests that vowel intelligibility was poor for Carnatic compared to Hindustani sung vowels. These differences in intelligibility could be attributed to the fact that these two types of singers may use different vocal tract configuration chosen for their respective style of singing and rhythmical pattern. More research investigating all different vowels in different languages and types of singing is required to determine the factors which might have caused these patterns of results in the present study.

Conclusion

On comparison of the sung vowel intelligibility across three different pitches in two groups of Indian classical singers, the vowels sung at high pitches in both males and female Hindustani singers were perceived as poor, whereas in Carnatic singer's intelligibility was affected in all the pitches. On comparison of the vowel intelligibility of sung vowels between two groups of Indian classical singers, Hindustani singers were more acceptable in terms of intelligibility rating than Carnatic singers by the listeners. This shows that singing condition itself imposes a factor in perception of intelligibility. More the knowledge about the factors affecting intelligibility, the more input it can have in singing pedagogy, particularly concerning communication with the audience.

Future research indications

In future, further study of the cognitive and acoustic factors relating to intelligibility, both for the singer (e.g. vowel, pitch height) and the listener (e.g. familiarity with the genre, tiredness) can be conducted and these will take us beyond merely the beliefs of singers and listeners into more objective findings. Overall there is great scope for psychological and acoustic methods to be used to investigate this area of research.

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