

# SUBJECTIVE AND ACOUSTICAL DATA ABOUT VOCAL EFFECTIVENESS IN WESTERN OPERA: PRELIMINARY RESULTS

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## ABSTRACT

The notion of "vocal efficiency" is difficult to define. In order to contribute to this definition, several data were obtained: first the evaluation of glottal efficiency  $E_g$  using an acoustic analysis was obtained. Second, we run a study asking subjects to find synonyms of vocal effectiveness. Results showed the prevalence of the perceptual aspect over the communication and production aspects. This concept depends on the vocal use by persons. The subjects insist on the notion of carrying power without fatigue whatever the context. Some acoustic measurements of singing power Ratio, an acoustic correlate of this perceptual aspect, were conducted in opera pieces with and without pianistic accompaniment: the singing-formant, a well known perceptive correlate of vocal effectiveness, was always present whatever the condition. So it appears that the concept of vocal effectiveness has a polysemous definition regarding subject vocal perception (auditor), production (singer) and communication (the public).

## INTRODUCTION

The term of vocal effectiveness is often taken as a synonym to glottal efficiency, which is measured traditionally in purely physical terms [11, 12]. From the engineering viewpoint, it may be defined as the ratio of vocal intensity to the glottal power, i.e.. subglottal air pressure times glottal airflow. However, particularly in artistic performance, vocal effectiveness may also include a subjective dimension. Vocal efficiency is a complex matter: it was here studied especially from both a cognitive point of view and a subjective one. In this communication, emphasis was put on vocal effectiveness (optimization of effort) rather than vocal efficiency (energy conversion and output).

After a short evaluation of glottal efficiency of our subjects in the first part of this communication, we evaluated the subjective definition of vocal effectiveness of a greater population through a questionnaire. Finally, in order to show the perceptive aspect of vocal effectiveness, we've conducted acoustic analyses.

## 1. EVALUATION OF GLOTTAL EFFICIENCY USING ACOUSTIC ANALYSIS

### 1.1. Method

17 professional opera singers (11 singers of the Bastille Opera House in Paris), were tested in this study, including 3 sopranos, 4 mezzo-sopranos and altos, 6 tenors and 4 basses. Ages ranged from 30 to 51 years ( $M=39\pm 6,3$ ). Number of years of vocal experience and training ranged from 6 to 35 years ( $M=16,7\pm 8,2$ ). There was 70% of French singers and three subjects were American. All received different kind of musical training.

According to Shoji et al. [8], the "H-Index" represents the first proposed acoustical measure of glottal efficiency. "Hi" ([haj]) was chosen to evaluate glottal efficiency since it provides an excellent test of glottal transformation from

voiceless ([h]) to voiced sound energy ([aj]). Indeed, Shoji found a high degree of correlation with the AC/DC ratio, which represents the transformation by the glottis of direct current airflow (DC) into alternative current airflow (AC). AC/DC ratio is a standard aerodynamic measure of glottal efficiency.

Our subjects were recorded in a soundproof room with a Digital Audio Tape, a cardioid microphone placed at 40 cm from the mouth. They were asked to pronounce five spoken and five sung "hi" at whatever pitches. The power ratio of [h] to [aj] was calculated from power peak of each measure from the power envelope.

### 1.2. Results

H-Index is higher in singing than in speech in our population; so, according to Shoji [8], singing quality is more efficient than speaking quality for our subjects ( $t_{17}=-3,74$ ;  $p=0,001$ ; fig.1). The mean of our subjects in spoken [haj] is comparable with Shoji's results and is greater than in pathologic voice [8].

However, our standard deviations are greater than Shoji's one, probably because of the native language of our population: this measure depends on the way each one pronounced the sequence "hai" in his native language. For our American subjects, the standard deviation is similar to Shoji's results; so supplementary measures should be done in speech and singing to compare our results with Shoji's ones.

### 1.3. Discussion

#### 1.3.1. Glottal efficiency ( $E_g$ ) values for singers.

According to Schutte [6], if one considers energy, trained singers are no more efficient in their use of their larynxes than untrained persons. Moreover,  $E_g$  values between untrained and trained male and female subjects showed non significant differences in Sulter and Wit [10].

#### 1.3.2. Problems with $E_g$ definitions and calculations.

Difficulty of measuring subglottal air pressure makes this vocal efficiency impractical as a routine vocal function test [9]. Moreover, its calculation doesn't include a cost-benefit ratio for vocal health and long term performance, an important parameter obtained in our second part. And in all studies, the efficiency is characterized by large standard deviations, indicating large variations in individual values. Beside that, it does not mean that the greater the efficiency, the better the glottal function in a physiologic sense: hyperfunctional voice such as ventricular phonation shows a very high value [9]. Finally, the efficiency of a trained singing voice is not reflected in the values of the subglottic pressure and airflow rate, but it will have its origin in the proper use of vocal tract tuning. [7] So vocal effectiveness in opera singing should not be approached only by acoustic measures such as the H-Index or aerodynamic data to determine the glottal efficiency. Other factors should be taken into consideration.

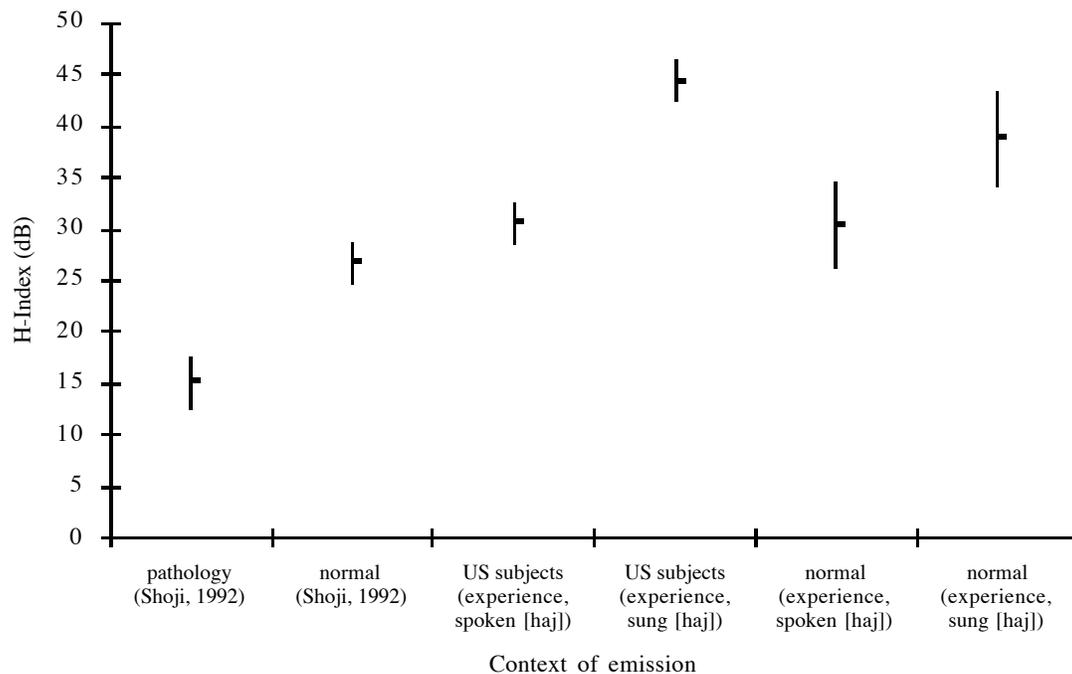


Figure 1. Mean Values and Standard Deviations of H-Index in differents contexts of emission.

## 2. INDIRECT FINDINGS FROM A QUESTIONNAIRE

### 2.1. Method

Our point here is to determine the vocal effectiveness from a cognitive point of view [1]. In our study, sixty persons (singers and non singers) were asked to find synonyms of vocal effectiveness in a singing and speaking context ("Pourriez-vous donner un synonyme de "efficacité vocale" dans la parole ? Pourriez-vous donner un synonyme de "efficacité vocale" dans le chant?").

A five pages questionnaire was submitted to the subjects. It was divided in two parts and was preceded by an explanation: the first part was designed to obtain informations about the subjects (identity, kind of training, profession, vocal habits). The second one consisted in open questions about "vocal effectiveness" in speech/singing. In this paper we consider only the question concerning synonyms ("synonymes") of the word "vocal effectiveness" ("efficacité vocale").

Differences between singers and non singers in one hand, and vocal effectiveness in speech and singing on the other hand, were tested with significance with Yates chi-squared statistics ( $X^2$ ) for prevalence statistics.

### 2.2. Results

**2.2.1. Population.** A total of 64 questionnaires was analyzed: 77,1% return rate (35 non singers and 29 singers); 72,4% women singers and 68,6% female the non singers. The mean age was similar for the singers (37,9 ( $\pm 11,3$ )) and non singers (39 ( $\pm 13,5$ )). A majority of the women singers were soprano (a total of 14, a proportion of 48,2% of the singers), 6 were mezzo-soprano and one was alto. For what considering the male subjects, 5 were barytones (17,8% of the total singers), one was alto, another was tenor, and one was bass.

Among the non singers and singers, there were a number of persons using their voice professionally (singers: 36% of singing teachers; non singers: 25,6% of teachers)

**2.2.2. Main categories.** The responses given by the subjects about the meaning of vocal efficiency (either in speech or singing context), lead us to make up five classes: 1. Perception efficiency with hedonic category as sweet voice ("voix agréable"), beautiful ("belle"), seductive ("séduisante"), melodious ("mélodieuse") and acoustic category as audible voice ("voix audible"), powerful ("qui porte"), clear ("claire"), sonorous voice ("voix timbrée"); 2. Communication or "output" efficiency : to pass on a message ("transmettre un message"), to pass on emotions ("transmettre des émotions"), very "others oriented" ("se donnant" à autrui) without being aggressive ("sans agresser autrui"); 3. Production efficiency: tireless voice ("voix sans fatigue"), economical voice (not effortful, endurance), good technical skills ("bonne technique vocale") and relaxed trained ("détente"); 4. Contextual conditionings and variability of the voice : adaptability of the voice ("adaptation, souplesse"), manageability; 5. Others.

**2.2.3. Vocal efficiency in speaking context.** The use of the five different classifications between singers and non singers were nearly the same (table 1): the prevalence of "perception efficiency" over all other categories was significant. ( $X^2=22,9$ ;  $p=0,0001$  between the perception class and the production one for the non singers;  $X^2=16,7$ ;  $p=0,0001$  for the same difference by singers).

But each person could write several synonyms and singers used more synonyms than non singers ( $N=2,41\pm 2,56$  against  $N=1,74\pm 0,85$ ;  $p>0,05$ ). However, these results remain true if one considers only the first synonym written by each subject.

VE in speech	singers	non singers
1. "perception" (acoustic & hedonic)	43%	49,20%
2. "communication"	22,80%	22,90%
3. "production"	15,70%	16,40%
5. "adaptability"	7,10%	3,30%
4. others	11,40%	8,20%

VE in singing	singers	non singers
1. "perception" (acoustic & hedonic)	34,30%	45,30%
3/2. "communication"	21,40%	26,40%
2/3. "production"	25,70%	15,10%
5. "adaptability"	4,30%	3,80%
4. others	14,30%	9,40%

Table 1. Percentage of obtained answers for "synonyms" of vocal efficiency in speech (1a) and singing (1b) for singers and non singers subjects. VE: vocal effectiveness. "1., 2. ...": ranks of the classes; 3/2: third rank for the singers and second rank for the non singers.

**2.2.4. Vocal efficiency in singing context.** There were great differences between singers and non singers: for the non singers, a slight decrease of the "perception efficiency" for the benefit of the "communication efficiency" was observed from speaking to singing (other classes were similar). The answers of singers were different from the non singers (from 15,1% to 25,7% for the "production efficiency", see table 1b). Even though the "perception efficiency" was predominant upon the "production efficiency" by the non singers ( $X^2=20,2$ ;  $p=0,0001$ ), it wasn't the same for the singers ( $X^2=1,36$ ;  $p=0,24$ ).

But, like in the speaking context, each person could write several synonyms and singers used more synonyms than non singers ( $N=2,41\pm 3,52$  against  $N=1,51\pm 0,95$ ;  $p>0,05$ ). However, these results remain true if one considers only the first synonym written by each subject (from 14,3% (non singers) to 32,1% (singers) for the "production efficiency").

## 2.3 Discussion

**2.3.1. Prevalence of "perception effectiveness".** The most important result is the prevalence of the perception category ("efficacité de perception"). Production efficiency is used to a maximum of a third of the subjects. Indeed, efficiency in human performance may not be measurable in purely physical terms but may include psychophysical dimensions. For example, in classical artistic performance, the *perception* of ease, fluency, and coordination is often more relevant (at least to the observer) than actual efficiency. Eg isn't the only meaningful measure of vocal efficiency that can be defined [12]. In fact, singing is mainly a listener oriented task.

**2.3.2. Influence of vocal use.** It is interesting to notice that the subjects who use their voice professionally (singers, teachers) were more sensitive to the category "production" than the other ones. Indeed, "Unlike non singers, most singers were taxed by their voice" [4].

**2.3.3. Carrying voice and timbre.** It's the most important result in our study. In the first category "acoustic" (within "perception"), the carrying voice (39% of the the 64 subjects' answers) and timbre (26%) were the most important criteria used to define the vocal effectiveness in singing; This goes well in line to our previous results on the perceptual effect of the the singing formant when 54 subjects were asked to freely judge the perceived difference between and original excerpt of a CD Record with singing-formant, and the filtered version (without singing-formant) [3].

Indeed, according to Winckel [13] and Schultz-Coulon [5], there is a relationship between carrying voice without fatigue and vocal effectiveness.

**2.3.4. Communication effectiveness .** The class order wasn't the same in speaking (second rank) and in singing (third rank) but it represented the fifth of answers in the two contexts. So a part of vocal effectiveness include qualitative aspects of the professional singer's training such as communication with the audience.

As seen by these results, a notion of vocal effectiveness seems to correspond to a slightly different concept in singing and in speaking; the communicative aspect is considered as more important than production aspect in speech. Thus the definition of vocal effectiveness in speech and singing seems to be polysemous: the singer must manage organically his voice, taking into account of perceptual qualities and communication with the audience.

So that it appears that apart from the vocal source, other parameters should be considered. Indeed, talking about vocal effectiveness is mainly like talking about carrying voice. This connection between carrying voice and vocal effectiveness has been developed by Winckel [13] and Schultz-Coulon [5] . According to Schultz-Coulon, the "vocal efficiency" concept is first of all a question of ability to carry with a special timbre (voice's clarity, aliveness, brightness and "ring"). In a physiological point of view, giving energy and carrying voice power are not so well connected. It's to say that the more a singer is getting a carrying voice, the less he's asked to give energy.

## 3. SUBJECTIVE ASPECT OF VOCAL EFFECTIVENESS

The term "carrying voice" (whatever the context) was most frequency used among synonyms of vocal effectiveness. For checking this assertion, each subject (same population as the section 1) was recorded singing opera pieces in two contexts: context 1: a cappella, context 2: with a headphone pianistic accompaniment (with less vocal feedback). The experience was done in a soundproof room with a cardioïd unidirectional Microphone placed at 40 cm from the mouth. Opera pieces were recorded on a Digital Audio Tape and Intensity was calibrated with a Sound Level Meter Brüel & Kjaer. The mean intensity of the piano was at 65 dB SPL.

From these recordings, measurements of singing Power Ratio [2] were done from Long Term Average Spectrum: this parameter is defined by the amplitude power ratio of the singing-formant and the greatest peak amplitude between 0 and 2 KHz. Indeed, Winckel [13] has shown a clear relationship between the presence of the singing-formant and the notion of the vocal effectiveness.

This comparative acoustic analysis between the two contexts showed non significative differences. ( $t_{16}=-2$ ;  $p>0,05$ ;

fig. 2). So the singing-formant, a vocal effectiveness component, was present in both contexts. We project to do

other experiences with noise instead of the piano.

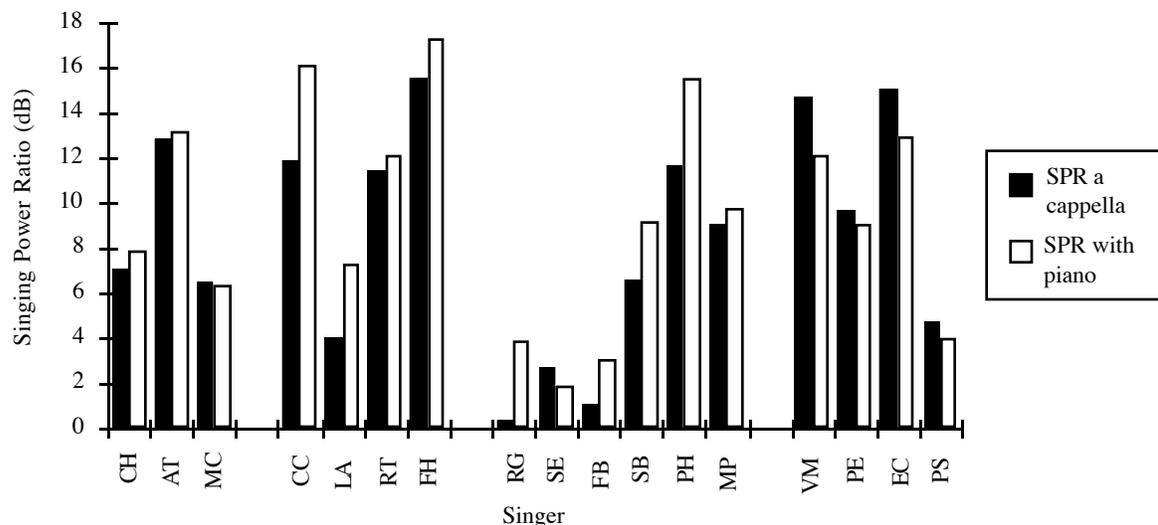


Figure .2 Singing Power Ratio (SPR) of the 17 subjects.

### CONCLUSION

Our preliminary results show that the notion of "vocal effectiveness" ("efficacité vocale") doesn't correspond to a single physical dimension; it's defined with a great number of parameters. In particular, this notion doesn't correspond to exactly the same concept for singers and non singers, and for people who use their voice professionally or not. A vocal production can be considered as effective ("efficace") also if it doesn't have a high glottal efficiency. In terms of pedagogy, insisting of the concept of vocal effectiveness is one of the main way to improve a singing voice and also a way on voice therapy.

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