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ASSESSING VIBRATO QUALITY OF SINGING STUDENTS

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Many studies have been carried out on vibrato in the singing voice, though usually on singing of professional singers. In the present study we examine vibrato quality in sustained notes as sung by students, rather than professionals, in an attempt to find objective measures for assessing vibrato quality in singing students. A set of 78 notes was assessed subjectively by 5 experiences musicians. A set of acoustic measures was then extracted, and analyzed statistically to obtain two indicators: presence or absence of vibrato, and in the case of presence – an indication of vibrato quality. Discrimination between presence and absence of vibrato was 82% correct; the predictor of vibrato quality achieved a significant correlation coefficient of 0.7395 with the subjective judgments.

I. INTRODUCTION

Vibrato in the singing voice has been the subject of several previous studies. Recent studies have focused on quantitative analysis of vibrato parameters, examining the rate of pitch modulation, changes in this rate, and depth of pitch variation [1,2].

Some of these studies have tried to find correlations between acoustical parameters and perception of vibrato quality. These were conducted on the vibrato of accomplished singers. From their conclusions, it seems that perceptual evaluation of vibrato quality in these cases is strongly influenced by individual musical taste, since these singers usually have very good control over their vibrato parameters.

A previous study we carried on the effect of vocal warm-up on singer's voices [3], on the other hand, left us with the impression that amongst students of singing, quality of vibrato varies to a very large extent. This motivated us to examine whether some acoustic measures could be found, that would correlate well with perceptual judgments made by singing teachers. Eventually, this could lead to a form of visual feedback that would aid these students in assessing their vibrato quality.

In the present study we used the same recordings that were used in the warm-up study [3], and submitted them for judgment of vibrato quality to 5 singing teachers. We then carried out a detailed acoustic analysis of the pitch over the closing two seconds of each recording, using various quantitative measures extracted from the raw pitch contour. Statistical analyses were then applied to find the acoustic measures which correlated best with the subjective assessment of vibrato quality.

II. METHODOLOGY

Participants: Twenty young female singers participated in this study. All participants had professional classical voice training for a mean period of 5.4 years (SD = 2.9). Sixteen singers were conservatory students, and the remaining four were graduates of a music academy. Overall mean age was 18.62 years (SD = 3.2), mean weight was 61.5 kg. (SD = 13.4) and mean height was 164.9 cm. (SD = 6.1). All singers were healthy, with no remarkable medical history.

Recording procedures: Participants were recorded individually in a quiet room while sustaining the vowel /a/ in three different pitches: 20, 50 and 80% of their vocal range. Each reference tone was presented by a piano in a random order, and the singer was asked to sustain the produced vowels (target tones) as accurately as possible for 3-5 seconds. The singers were not specifically instructed to produce vibrato in their sung tones. All vocal productions were recorded through a microphone (ACO Pacific, Inc.) situated approximately 15 cm from the subject's mouth, using a Sony-TCD D7 digital recorder (Sony, Tokyo, Japan). Sampling rate for the recording was set for 48 kHz (16 bits per sample). Vocal productions of duration less than 2 seconds were also excluded from the analysis, leaving 78 recordings that were analyzed in all.

Subjective Evaluation: The 78 recordings that were chosen for this study were presented, in a random order, to five judges for evaluation. Of the judges, three were singers and two were musicians with extensive experience in accompanying singers. Mean age of the judges was 23 years (SD = 2.12).

Each judge was, independently, presented with a simple computerized questionnaire. For each recording, the judges were, first, required to decide whether it contained vibrato or no. If a recording was judged to contain vibrato, the judge was asked to rate its quality on a 4-point scale, where 1 represents "poor", 2 "fair", 3 "good", and 4 "very good". The judges were allowed to listen to each recording only once, yet they could advance through the recordings at their own pace. Recordings that were judged by four or more listeners as containing

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vibrato were considered, for the purpose of this study, as containing vibrato.

Acoustic Analysis: Vibrato is defined as a periodic variation in fundamental frequency. It is most often found to be closely sinusoidal, with a frequency in the range of 5 to 7 Hertz (see, for example, Prame's papers, [1,2]). We implemented a Pitch Detection Algorithm (PDA) in Matlab, based on the autocorrelation method. Although the original recorded productions varied in length between 5 seconds and 1.5 seconds, only the last two seconds of each recording were analyzed. Pitch detection was performed over successive 20 ms windows, with overlap of 10 ms, with a worst-case frequency resolution of 0.12 Hz. For the windowing scheme described, this resulted in 200 pitch points for each file.

Most previous studies performed relatively basic analyses on the raw data, usually measuring vibrato rate and extent. Evidently, when studying the vibrato of professional singers, the vibrato is steady enough for these to be the dominant factors in determining its quality. In contrast, in the present study, we found these features to be insufficient, and in some cases even inapplicable. In fact, the wide range in pitch contours produced by the students examined here, required the use of more generalize measures that would be able to detect whether vibrato exists at all, and assess its quality if it is present.

In order to do so, we implemented the methods used in detecting pitch itself. Since pitch is defined as periodic oscillation in the voice signal, periodic oscillation of the pitch can be measured with the same methods. We therefore applied two further analyses to the pitch contour: autocorrelation (after removal of DC) and the Fourier transform. Several illustrative examples are provided in Figures. 1-3. Figure 1 demonstrates a pitch curve, which was rated by the listeners, as not containing vibrato, Figure 2 demonstrates an unsteady vibrato, which was rated by the listeners at 1.4, and Figure 3 demonstrates an example of a steady vibrato, rated at 2.75. Each figure includes (from top to bottom): (a) the pitch contour, after average has been removed; (b) the autocorrelation of the pitch contour; (c) the Fourier transform of the pitch contour.

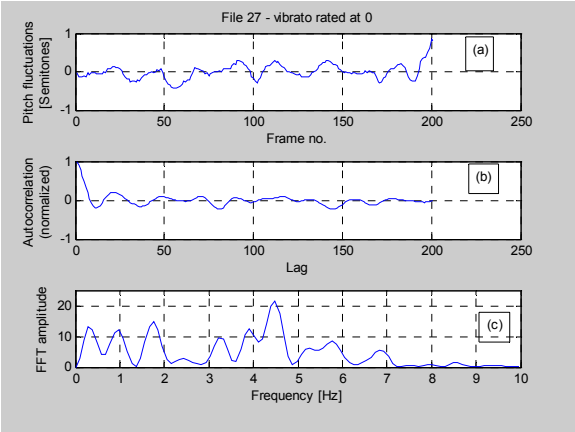

Fig. 1 – An example of a production with no vibrato

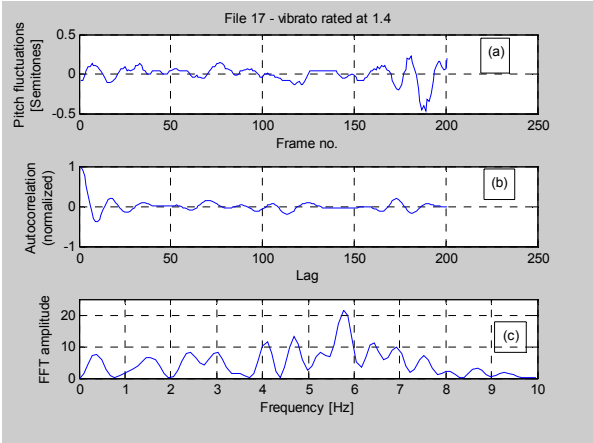

Fig. 2 – An example of a production with poor vibrato

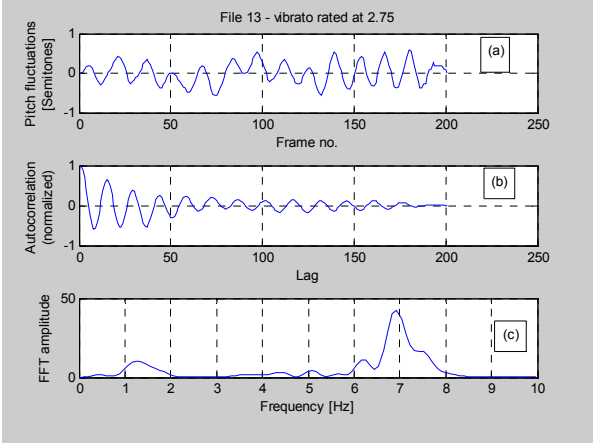

Fig. 3 – An example of a production with good vibrato

From this raw data, a series of several potential measures were then calculated:

1. Energy between 4.5 and 7.5 Hz as compared to energy between 1 and 10 Hz.
2. Energy between 5 and 7 Hz as compared to energy between 1 and 10 Hz.
3. Index and height of the first peak in the autocorrelation of the pitch contour.
4. Index and height of the first trough in the autocorrelation.
5. Variance of the pitch contour.
6. Mean and standard deviation of a curve representing local extent of vibrato
7. Several additional measures of peak height and width in the FFT of the pitch contour

III. Results

The analysis was carried out in two stages: the first to determine a measure for presence/absence of vibrato, and the second to find a measure that correlates with the perceptual judgment of vibrato.

A. Presence of vibrato

Logistic analysis was applied to the raw measures presented in the previous section, in order to find a predictor that would be in optimal agreement with the perceptual judgments. The results obtained by this predictor are summarized in table 1.

Table 1 – Classification results for vibrato existence

		Predicted		
		No	Yes	Total
Actual	No	20	8	28
	Yes	6	44	50
	Total	26	52	78

Table 1 shows an overall recognition rate of 82%. False positives are more prevalent (28%) than false negatives (12%).

B. Rating of vibrato

The acoustic measures were analyzed statistically in order to find a predictor that would correlate well with the judges' average rating of those recordings judged to contain vibrato. Eventually, it was found that a linear regression analysis applied to four measures gave a predictor that has a statistically significant correlation of 0.7395 with the judge's subjective ratings. These four measures were:

1. Height of the first autocorrelation peak
2. Absolute height of highest peak above 2 Hz in the FFT of the pitch contour
3. Width of the highest peak in the FFT
4. The number of spectral peaks above a third the height of the highest peak

C. Agreement between judges

Agreement among judges' ratings of vibrato quality was assessed using Kendall's coefficient of concordance, and yielded a value of 0.619 ($p < 0.001$). This analysis was based on the productions which were identified as demonstrating vibrato.

IV. Discussion

The present results show that relatively good agreement can be obtained between subjective and automated assessment of vibrato quality of singing students. Obviously, the agreement between the subjective and objective measures is bounded by the inter-judges subjective agreement variability.

The methods utilized here, on singing students can be expected to demonstrate a ceiling affect, when applied to recordings of professional singers – this will be examined, in the future, in further detail.

V. Conclusion

Acoustic measures of vibrato, which were conceived specifically for identification and evaluation of vibrato among singing students were shown, here, to provide a relatively reliable predictor of vibrato presence and quality as evaluated by listeners.

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