AM I IN TUNE OR NOT?

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ABSTRACT

Singers may sometimes deviate from the correct intonation patterns. It is not always evident why this kind of deviations happen. The present study addresses the issue of whether a singer is aware of how accurate her/his intonation is (or was) during the performance. 13 singing students were asked to perform a vocal exercise which consisted melodic intervals of the size of one, six and seven semitones. After the performance, each subject was asked to indicate by memory which notes she/he was able to intone correctly and which not. As the third step in the experiment, the subjects had to listen to their own performance again and, as previously, to indicate both the location of the intonation errors as well as their direction. The equally tempered tuning was used as a reference system. Some subjects were unable to perform the task altogether while the standard deviation for other subjects never was more than 14 cents. Minor seconds were performed more accurately than tritones. Those intervals which the singers selected out as mistuned during the immediate post-experimental interviews, were not different from the other performed intervals in a statistically significant manner. The singers' ability to perceive their own intonation errors was worse during the performance itself when compared to their ability to do the same during the subsequent listening to their recorded performance. In post-performance judgments, the magnitudes of reported mistunings were statistically significantly greater than the magnitudes of other, unreported mistunings, The ability to sing with a correct intonation seems largely to be dependent on skills and training of the performer.

1. INTRODUCTION

The ability to sing without intonation errors belongs to the most important professional skills of a singer (Kagen 1950, Pierce 1999). Singing without errors means that a listener should perceive the produced pitches as the elements of a musical scale which the musical work performed is based upon. The Western musical culture relies largely on the equally tempered scale (Rossing 1990, Burns 1999). Intonation practices, however, may to a significant extent deviate from the theoretical model of the equally tempered scale (Francès 1988, Ternström and Sundberg, 1988, Ward 1970). It has been found that, depending on the musical context, even the expert listeners may sometimes rate as correct the intonation of the tones if they fall into the corridor of up to ±30 cents (Sundberg 2001). In general, most experts perceive the tones as to be in tune if the deviations are not exceeding the area of ± 7 cents (ibid). It should be noted that the correct intonation does not necessarily mean its correspondence to the equally tempered scale (Morrison and Fyk 2002). However, consistency in reproducing the same musical interval under similar conditions is a characteristic of a singer as to what extent he/she is able to exercise control over the pitch domain during the performance. The standard deviation from the some kind of standard value (average or etalon) may be considered as a good indicator of this consistency.

Even very high-class singers may sometimes deviate from the correct intonation patterns, so that their performance is considered as incorrectly intoned. It is not always evident why this kind of deviations happen. Don't those singers possess an musical ear enough trained, in order to be able to control their vocal production? In this study we have investigated the ability of singers vocally to reproduce melodic intervals which start at one and the same pitch, as well as the singers' perception of their own intonation errors. A simple tuning fork was used for the pitch calibration in the experiment.

2. METHODS

We asked 13 singers to perform a series of melodic intervals which all started with the same pitch. Singers were provided with the written score of the material (see Figure 1) at the beginning of the experiment. They had themselves to determine the pitch of the first note in an interval. High voices had to start two semitones higher the conventional tuning-fork A4, namely at B4 (or B3 for male), and low voices had to start two semitones lower than the tuning-fork reference, namely at G4 (or G3 for male). The subjects were asked to perform six intervals with their voice: minor second, tritone, and pure fifth, all intervals both in ascending and descending modes. The performances were recorded using the Kay Elemetrics Computerised Speech Laboratory Model 4400 and the AKG 420 head microphone. Each singer had to repeat the task four times. At the beginning of each repetition subjects were requested to calibrate their performance with the tuning fork. In the first, third and fourth repetition, singers were asked to vocalize the "interval note" with the vowel /a/ and, in the second repetition, with the vowel /i/ (see Figure 1). At the beginning of the third repetition, the subjects were asked to remember all the intonation errors they perceived themselves during the performance. After the performance of the third series, subjects were asked to record their own intonation errors in the score, using arrows at appropriate places for this purpose. After this procedure, the recorded third repetition of the interval series was played to a subject and he/she was asked again to record in the score the noticed intonation errors. Subjects were permitted to use a tuning fork for this task. Finally, the fourth repetition had to be performed as the first one, i.e. on the vowel /a/, and with paying attention neither to possible intonation errors, nor to their recording. Students, both undergraduate (starting

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from the second year) and graduate, of the Estonian Academy of Music, participated in the experiment. Some of the master students were in fact highly professional singers who regularly perform on the opera or concert stage. One participant (MY) was employed as the choirmaster in an internationally recognized top-level chamber choir; he at the same time frequently performs as a soloist as well as a member in vocal ensembles. Another participant (IO) possessed absolute hearing.

Figure 1: The score of a series a melodic intervals performed by 13 singing students.

The recorded materials were acoustically analyzed using the Praat 4.07 software. For each performed tone, its pitch was determined. For that purpose, a stationary segment with the duration of at least one second was selected; the pitch of the segment was considered representative of the whole tone. As the next step, performed interval magnitudes and their deviations from the equally tempered counterparts were computed in cents, as well as the deviations of intervals from the equally tempered chromatic scale with respect to A4 = 440.38 Hz. Common statistical analysis was applied to the obtained data.

3. RESULTS

Two singers were unable to perform the task because of their inadequate ability of sight-reading. The group of the rest thus consisted of 11 subjects.

In the results, there was no correlation between the intonation accuracy and the vowel quality. No statistically significant differences were detected between the second (which used the vowel /i/) and the fourth performance series (which used the vowel /a/). We conclude that, even if there may occur some interdependence between the vowel quality and the magnitude of the sung intervals, it is certainly less than the normal variability of the intervals' sizes in musical performance.

3.1. Accuracy of the performance of the initial tone

One singer out of 11 systematically missed the expected pitch of the very first tone in the experimental series (i.e., the tone which was expected to have been determined by taking two semitones up or down from the tuning-fork A4) by one to two semitones. The data of this singer were not included in the statistical analysis.

In average, the pitch of the initial tone was intoned 4 cents lower with respect to the equally tempered etalon. The standard deviation was 25 cents and the pitch distributions were close to normal. Some singers systematically intoned the first tone lower by approximately one third of a semitone with respect to the equal temperation, in all performed intervals (e.g., AK, TK). Another singers (e.g., KE) systematically intoned the first tone higher by approximately one fourth of a semitone in all cases.

3.2. Stability of the first tone of an interval

We analyzed the stability of the pitch of the first tone in all intervals within individual series. The pitch of the first tone varied within a range of 48 cents, with the standard deviation of 18 cents in the average. There were more stable subjects with the 27 cent pitch variation range (RJ) as well as less stable subjects with the 89 cent pitch variation range (JL).

3.3. Deviations from the equally tempered interval values

	N	Mean	SD	Min	Max	p
m2 down	44	-9	14	-37	13	0.7
tritone down	39	3	31	-75	59	0.4
p5 down	43	7	20	-38	39	0.7
m2 up	44	-11	14	-43	15	1
tritone up	42	5	39	-81	70	0.9
p5 up	43	16	32	-52	88	0.9
all together	255	2	28	-81	88	0.1

Table 1: The statistical data of the intervals' deviations from their corresponding equal tempered counterparts. N – the number of cases; Mean – the average value of a deviation, SD – standard deviation, Min – deviation of the most narrowly sung case; Max – deviation of the most widely sung case; p – values of the Kolmogorov-Smirnov test: we considered that the distribution is sufficiently close to normal if $p>0.05$. (The deviations bigger than 90 cent were excluded from the data as apparent mistakes in determining the interval category by a singer).

Among the three interval values, minor seconds were intoned in the most stable way, with their standard deviation being only 14 cents. At the same time, they were performed slightly narrower than according to the equal temperation: ascending intervals were 11 cents less and descending intervals 9 cents less, respectively. Performance was the most unstable with the tritones. The standard deviation for the ascending tritones was equal to 39 cents and descending tritons 31 cents. In other words, 70 per cent of the tritones are located in a 'corridor' with the magnitude of 78 cents which is close to a semitone. The average size of the tritone, however, was closer to the equally tempered value. The average size of the pure fifths was slightly more (by 16 cents for ascending and 7 cents for descending intervals) than their equally tempered counterparts. All interval distributions were sufficiently close to normal (Figure 2).

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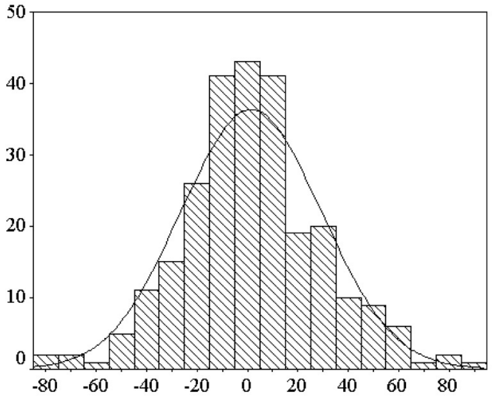

Figure 2: Deviation of the performed intervals from their equally-tempered counterparts. Horizontal axis: deviation in cents; vertical axis: number of cases. Standard deviation of the distribution equals 28 cents, and the mean value is plus 2 cents. Continuous line: approximation to the normal distribution.

3.4. Deviations from the equally tempered scale values

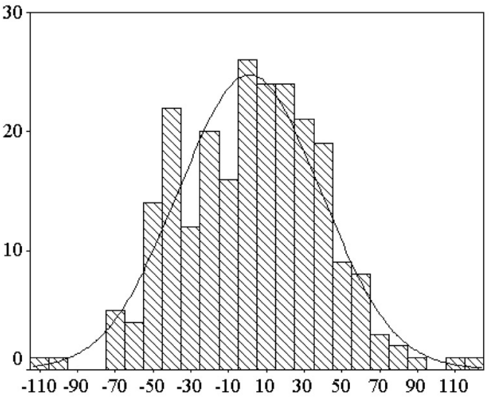

Figure 3: Deviation of the performed individual tones from their equally-tempered counterparts. Horizontal axis: deviation in cents; vertical axis: number of cases. Standard deviation of the distribution equals 38 cents, and the mean value is plus 1 cent. Continuous curve: approximation to a normal distribution.

Next, we tried to compare the intonation of individual tones in our experiment, rather than of intervals, to the normative scale. If we project performance of single tones onto the equally tempered scale, with the reference of A4=440 Hz, we can see that the variation of performed individual pitches with respect to the theoretical scale values was greater (with the standard deviation of 38 cents) than the variation of performed intervals with respect to the theoretical interval values (with the standard deviation of 28 cents). This suggests that the subjects seem to have intoned the tone series in terms of intervals rather than in terms of fixed scale steps. In other words, when performing an interval, the singer seems to have chosen the target pitch with respect to the previous pitch, rather than with respect to some abstract scale schema (cf. Figures 2 and 3).

For some singers (e.g., JL) we observed systematic increase or decrease of the used pitch range within the whole tone series (Figure 4).

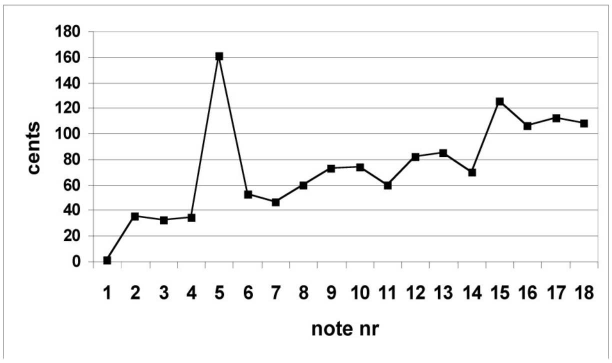

Figure: 4. Singer's (JL) tuning is drifting up (dots correspond to deviation from the equally tempered scale); Note #5 – falsely intoned pitch (more than 1 st too high).

3.5. The singers' ability to notice their intonation errors

Altogether 19 cases of mistuning were claimed by the subjects during the immediate post-experimental interviews (Table 2). If we assume the expected correct standards to be the equally tempered interval values, then nine claims out of 19 were correct and 10 claims incorrect. But those intervals which the singers selected out as mistuned were not different, however, from the other performed intervals, in a statistically significant manner.

The number of claimed mistunings increased to 38 after the subjects had listened to and evaluated their own performance. Also the ratio of justified claims increased: if we assume, again, the equally tempered interval values to be the correct targets then 31 mistunings were picked up correctly and only seven cases by mistake. The magnitudes of reported mistunings were significantly greater than the magnitudes of other, unreported mistunings (Mann-Whitney Rank Sum test, p=.003). If we, however, compare the mistuning of individual tones to their equally tempered etalon values, then the reported mistunings are not statistically significantly greater than mistunings of the rest of the tones. This is true both as to the immediate post-experimental interviews as well as to the further listening-based evaluation of one's own performance.

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	KT	AF	KE	IO	JT	PR	JL	RJ	TK	RV	MY
m2 down	3	-5	-13	-19	-2	-23	-34	-2	***-1***	7	-5
tritone down	***-23***	14	3	22	5	**58**	-127	-38	**19**	6	7
p5 down	***-4***	***-10***	7	**34**	8	-38	-13	***11***	39	102	12
m2 up	-6	1	4	11	**2**	-43	-14	-20	***-26***	-6	-6
tritone up	***51***	41	-19	-39	39	***-66***	-15	53	-15	**4**	5
p5 up	-8	35	4	10	***-10***	-52	6	51	**36**	**4**	5

Table 2: Data on mistunings are presented for three melodic intervals in ascending or descending modes (rows) and for 11 singers (columns). Mistunings detected by the singers themselves during immediate post-experimental interviews are indicated in boldface. If a singer could indicate the direction of her/his mistuning correctly, the respective value is presented in boldface and italics. If a singer indicated the direction of mistuning incorrectly, the value is presented boldface and underlined.

4. CONCLUSIONS

Results of our investigation demonstrate that a singer's ability to exercise control over her/his intonation, i.e. over magnitudes of the intervals which she/he performs, is considerably less than the considered standard of ± 7 cents (which, as it is thought, leaves the performed interval during the listening unnoticed as an incorrectly intoned one). It is also evident that a singer's ability to evaluate her/his own voice parameters, including the intonation accuracy, is considerably less compared to when the singer is listening (live or to the recordings of) other singers. It seems that the ability to exercise control over the intonation of one's own voice is developed to a different extent for different singers. It also seems that individual intervals in a melody are intoned independently, i.e. without reference to the scale as a general framework.

There seem to be different aspects of the singer's ability to control her/his intonation behavior. The first aspect is related to existence (or lack) of an internal etalon for the target pitch to be produced, which may be related to the singer's memory for different pitches. The second aspect is related to the singer's ability to produce the required target pitch according to this internal etalon. The third aspect is related to the singer's ability adequately to perceive pitch of the note which she/he has just produced. It may be of considerable importance how a singer is able strategically to divide her/his attention between the above three (and possibly more) aspects involved in the intonation behavior. We also believe that the relationship between the performed melodic patterns and the tonal context these patterns fit (or unfit) may influence the eventual acoustical outcome in singing.

It occurs likely that some singers who participated in the reported experiment may have yet underdeveloped some or all the above components vital for the correct intonation behavior. We hypothesize that, in order to keep deviations from the etalon pitch within the range of ± 7 cents, even a singer with a good musical reputation (like MY, IO, KT and RJ) may require some assistance from the accompaniment, i.e. that the correctly intoned pattern is very complicated to achieve in *a cappella* singing. This hypothesis should be investigated in a further study. Last not least, a good singing is characterized by many different features and, this way, we do not exclude that a listener with a good will may tolerate the intonation deviation in the cases when those other features are mostly or fully intact in the performance.

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