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Quantitative Voice Class Assessment of Amateur Choir Singers: A Pilot Investigation

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Abstract

The required pitch range (RPR), i.e. the pitch range that is determined by the music to be sung, is dependent on voice class (most commonly: soprano, alto, tenor or bass). Ideally, it should lie well within the boundaries of the physiologic voice range. In amateur choir singing however, the individual singer's choice of voice class does not necessarily result in optimal use of vocal potential. This study seeks to establish an objective, quantitative method to determine voice class, and to highlight unused potential with respect to voice range.

Twenty-one members of an amateur choir (15 female, 6 male) were examined by means of standard voice range profile (VRP) measurement. The RPR (as defined by the singers' chosen voice class) was compared to maximum phonational frequency range (MPFR) as determined by the physiological VRP measurement. The difference between the upper limit of the RPR and the highest pitch in the VRP, expressed in semitones, was defined as "upper reserve" (UR); the difference between the lower limit of the RPR and the lowest pitch measured with the VRP was defined as the "lower reserve" (LR). The "tessitura shift" (TS) was defined as half the difference between upper and lower reserve [TS=(LR–UR)/2)]. It is a measure of the offset of the RPR in relation to the MPFR, expressed in semitones.

Results with these participants indicated that the average physiologic voice range was 37.7 semitones (min 31, max 45). With the exception of the sopranos, all voice classes had more upper reserve than lower reserve, which was reflected by the average TS per voice class: soprano 2.33; other voice classes: –2.83 to –6.3. Results suggest that some individual female singers might profit from changing their voice class (from soprano to alto, or vice versa), in order to better exploit their physiological voice range. We concluded that upper and lower reserve measurements are well suited to indicate the degree of voice usage in extreme frequency ranges, whereas the TS can be used as an indicator of the "alignment" of RPR within the physiological voice range. Amateur choir singers' choice of voice class is a strategic decision that might crucially influence the singers' phonatory behavior, and thus their long-term vocal health. The indicators presented in this study may be useful for making such a decision.

Keywords

voice range, amateur choir singing, tessitura

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The human voice is capable of producing sound at a wide range of fundamental frequencies. In choir singing, the composer usually determines the notes (or pitches) of the performed piece. Ideally, there is a good match between the individual singer's vocal range and the notes to be sung. To the best of our knowledge, this study is the first formal investigation to test whether such an agreement is indeed reached in an amateur choir.

Hollien, Dew and Philips (1971) defined the maximum phonational frequency range (MPFR) as "that range of vocal frequencies encompassing both the modal and falsetto registers; its extent is from the lowest tone sustainable in the modal register to the highest in falsetto, inclusive" (p. 755). The MPFR is closely related to the data captured in the phonetogram or voice range profile (VRP), where the maximally loud and soft phonations throughout the entire frequency range are displayed in a plot of frequency against sound pressure level (Damsté, 1970).

Usually, the physiologic limits of the voice have been explored in VRP measurements, and thus the musical quality of phonation has not been used as a criterion for trial acceptability (Baken & Orlikoff, 2000). Some studies, however, focused on the *musical* (Awan, 1991) voice range, where only "quality" phonations were considered, e.g. such phonations, that a "singer would produce … in a performance" (LeBorgne & Weinrich, 2002, p. 39). In this kind of measurement, data acquisition would be dependent on the subjective definition of quality.

Pabon and Plomp (1988) have been the first to present a quantitative approach to introduce voice quality information into the VRP. More recently, Lamarche, Ternström and Pabon (2010) clearly distinguished between physiological and "performance" VRPs, and also provided some baseline data on highly trained female professional singers with respect to voice range that is "musically acceptable for the stage".

According to Seidner and Wendler (2004), voice classification applies mainly to performances in traditional (classical) opera and concerts. The German "Fach" system includes more than 20 sub-classifications (Large, 1984). Tables 1 and 2 provide an overview of the approximate singing fundamental frequency ranges and related pitches for the basic voice classes (in some texts also referred to as "voice categories" or "voice groups"), as indicated by several authors.

Table 1. *Approximate Singing Fundamental Frequency Ranges Per Basic Female Voice Classes According to Various Sources*

Female	Titze		Seidner and Wendler		*New Harvard Dictionary of Music*		Emmons and Chase	
Soprano	G3 (196 Hz) - D6 (1175 Hz)	31 ST	C4 (262 Hz) - C6 (1047 Hz)	24 ST	C4 (262 Hz) - A5 (880 Hz)	21 ST	E4 (330 Hz) - G5 (392 Hz)	15 ST
Mezzo-Soprano	E3 (165 Hz) - A5 (880 Hz)	29 ST	A3 (220 Hz) - A5 (880 Hz)	24 ST	A3 (220 Hz) - F5 (698 Hz)	20 ST	C4 (262 Hz) - F5 (698 Hz)	17 ST
Contralto	D3 (147 Hz) - D5 (587 Hz)	24 ST	D3 (147 Hz) - E5 (660 Hz)	24 ST	F3 (175 Hz) - D5 (587 Hz)	21 ST	Ab3 (208 Hz) - C5 (523 Hz)	16 ST

Table 2. *Approximate Singing Fundamental Frequency Ranges Per Basic Male Voice Classes According to Various Sources*

Male	Titze		Seidner and Wendler		*New Harvard Dictionary of Music*		Emmons and Chase	
Tenor	C3 (131 Hz) - C5(523 Hz)	24 ST	C3 (131 Hz) - C5(523 Hz)	24 ST	B2 (123 Hz) - G4 (392 Hz)	20 ST	D3 (147 Hz) - F#4 (370 Hz)	16 ST
Baritone	G2 (98 Hz) - G4 (392 Hz)	24 ST	G2 (98 Hz) - G4 (392 Hz)	24 ST	G2 (98 Hz) - E4 (330 Hz)	21 ST	A2 (110 Hz) - D4 (294 Hz)	17 ST
Bass	E2 (82 Hz) - E4 (330 Hz)	24 ST	D2 (73 Hz) - E4 (330 Hz)	26 ST	E2 (82 Hz) - C4 (262 Hz)	20 ST	F2 (87 Hz) - B3 (247 Hz)	18 ST

Note: Titze (2000); Seidner & Wendler (2004); the *New Harvard Dictionary of Music* (Koth, 2007); Emmons & Chase (2006). Emmons and Chase (2006, p. 313) give recommendations for the "safest and best range" instead of a pure description of vocal range. ST= semi-tone.

Singing voice ranges in choral music have usually been introduced via highest and lowest notes (pitches) to be sung by the singers of the various voice classes, and the resulting ranges have been expressed in semitones (see Table 1). For these ranges, the term *required pitch range* (RPR) is used throughout this manuscript. Usually, the RPR is non-negotiable, because it is determined by the composer of the musical piece to be performed. Naturally, amateur choir singing requires a smaller RPR than professional operatic solo singing.

The MPFR is a physiological measure that is expressed in Hertz, and the RPR is the de facto operational range of the voice, and it is specified in semitones. These two quantities can be related to each other mathematically[1]: A given note (pitch) can be converted into a frequency f by

$$f = 2^{\frac{DST}{12}} f_{A4}$$

where f_{A4} equals 440 Hz, and DST is the pitch difference from A4, measured in semitones. When performing music from the Baroque era, the pitch A4 is often defined to have a lower frequency, usually around 415 Hz. A known frequency can be converted to the corresponding musical pitch by

$$d = 69 + 12\log_2\left(\frac{f}{440}\right)$$

where f is the known fundamental frequency, and d is the MIDI note number, starting with C-1 (ca. 8.176 Hz) (The MIDI Manufacturers Association, 1995).

The tessitura is "an average pitch level of a song or piece of a song" (Titze, 2000, p. 191). Thurmer (1988) proposed a statistical method ("tessiturogram") to graphically analyze the frequency of note occurrence within a vocal part. A similar approach has been used by Fussi, Gilardone and Paolillo (2007), who introduced the "vocal score profile" as a tool to compare the statistical distribution of notes in various opera

[1] Strictly speaking, relating fundamental frequency to pitch is like comparing apples with pears: Fundamental frequency is a measure of the repetition rate of vibrations in a physical system, i.e. the number of oscillations per second, measured in Hertz (Hz) (Rossing, 1990). Pitch, on the other hand, is a subjective perceptual quantity. It is formally defined as "that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high" (ANSI, 1960).

roles with the voice range profiles of professional opera singers actually performing these roles. This method quantitatively compares the physiologic voice range with the performance requirements (with respect to singing fundamental frequency) of a particular piece of music to be performed in a German "Fach" context. Such a comparison of maximum phonation frequency range (MPFR) vs. required pitch range (RPR) has not to our knowledge been documented for amateur choir singing.

The purpose of this pilot study was to establish an objective, quantitative method to determine voice class, and to highlight unused potential with respect to voice range. We accomplished this purpose by evaluating the physiological tonal voice range capabilities (i.e., the MPFR) of the singers (N = 21) in an amateur choir, and by relating these findings to the pitch ranges that the singers were supposed to sing (their RPR) as defined by their chosen voice class This study was guided by the following research question: How well are the singers in this amateur choir assigned to voice classes? A secondary goal of this study was to obtain some indicators about the singers' vocal health status, which was addressed by collecting data with a questionnaire designed for this purpose.

Method and Procedures

Participants

Participants were 21 members of an amateur church choir based in the county of Salzburg. Fifteen choir members were females, singing either soprano (n = 6) or alto (n =7); two singers indicated that they alternatively sing soprano or alto, thus for the purpose of this study they have been considered to be mezzo-sopranos. The 6 male choir members were either tenors (n =3) or basses (n = 3). Only one choir member (tenor FO) had received individual vocal training (3 years). Participants' ages, information on medication, and self-reported, subjective assessment of vocal health were collected at the beginning of each recording session by means of a questionnaire (See Appendix). These data were analyzed by an ENT-physician. Each of these participants was assigned to one of these two groups: A = no symptoms that would indicate clinical evaluation; B = symptoms that indicate clinical evaluation.

VRP Measures

The singing fundamental frequency range of the participants was extracted from the voice range profile measurement. Starting with a comfortable fundamental frequency, the participants were asked to produce sustained phonation with a comfortable effort on the vowel /a/ for at least three seconds. The fundamental frequency was then reduced by steps of two semitones (participants were asked to match the pitch of a stimulus tone), and the task was repeated until the lowest possible fundamental frequency was reached. This procedure was then repeated from the previously used comfortable fundamental frequency upwards until the upper limit of the voice range was reached. At the extreme ends of the voice range, fundamental frequency was increased/decreased by steps of one semitone. As opposed to the definition of MPFR by Hollien et al. (1971), we consider the fundamental frequency range to encompass also the whistle register (Svec, Sundberg, & Hertegard, 2008). Thus, no upper limit for fundamental frequency was imposed. On the contrary, female participants were encouraged to "let the voice flip" to this upper register if possible. The participants were asked to repeat the entire procedure at minimum and maximum intensity levels, respectively.

The VRP-measurements were conducted in a room with "living room acoustics" (Schutte & Seidner, 1983). Acoustic data was captured with a head-mounted microphone of type Sennheiser MKE platinum-C. The microphone was mounted at a spectacle frame (without glasses) worn by the participants. The microphone was attached at a distance of 7 cm and 45 degrees horizontally to the participant's mouth. The acoustic signal was pre-amplified with a MindPrint Di-Port, digitized at a sampling rate of 48 kHz with a RME Hammerfall DSP Multiface external sound card, and stored in 16 bit PCM "wav" format in a PC.

Data analysis was performed with a DSP class library written in C++ by the Author CTH (Herbst, 2008). The fundamental frequency of phonation was determined with an auto-correlation algorithm, as described in Boersma (1993). To assess the correctness of fundamental frequency extraction, a synthetic continuous tone (created by additive synthesis: five harmonics with a rolloff of -12 dB per octave) was perceptually matched to the phonations at the extreme ends of each participant's MPFR, and the fundamental frequencies were compared.

Calculation of Derived Parameters

The fundamental frequency range of a voice class in amateur choir singing is mainly dependent on the choice of musical pieces and may vary from choir to choir. Because the ranges specified in the *New Harvard Dictionary of Music* (1986) appeared in good accordance with musical practice, we used them as the voice class dependent required pitch range (RPR), and based the following calculations on these data:

The difference between the highest pitch in the MPFR and the upper limit of the RPR, expressed in semitones, was defined as "upper reserve" (UR). The difference between the lower limit of the RPR and the lowest pitch of the MPFR was defined as the "lower reserve" (LR). Figure 1 (following page) uses data taken from one participating soprano's voice range profile to illustrate comparison of MPFR and RPR.

In Figure 1, the RPR is not perfectly centered within the MPFR, resulting in a larger LR (11 semitones) as compared to the UR (5 semitones). Consequently, this singer has a positive tessitura shift (TS) of 3 semitones.

The "tessitura shift" (TS) has been defined as half the difference between lower and upper reserve:

$$TS = \frac{LR - UR}{2}$$

The tessitura shift is a measure of the offset of RPR in relation to the MPFR, expressed in semitones. A positive tessitura shift suggests that a choir singer is singing higher than her average MPFR, and vice versa for a negative tessitura shift. If, for instance, the upper reserve is larger than the lower reserve, the tessitura shift would be negative.

The normality of the calculated TS data was assessed by a Shapiro-Wilk normality test (p = 0.7528). The means of the TS data per voice class were compared by a one-way ANOVA analysis. The confidence intervals on the differences between the TS were calculated post-hoc with Tukey's honest significance test (the employed implementation of this test allowed for the adjustment for sample size in unbalanced designs). The distribution of the TS means over the two vocal health assessment categories A and B (defined earlier in this text) was assessed with a t-test. All calculations were performed with the R statistics package, (R Core Team, 2012).

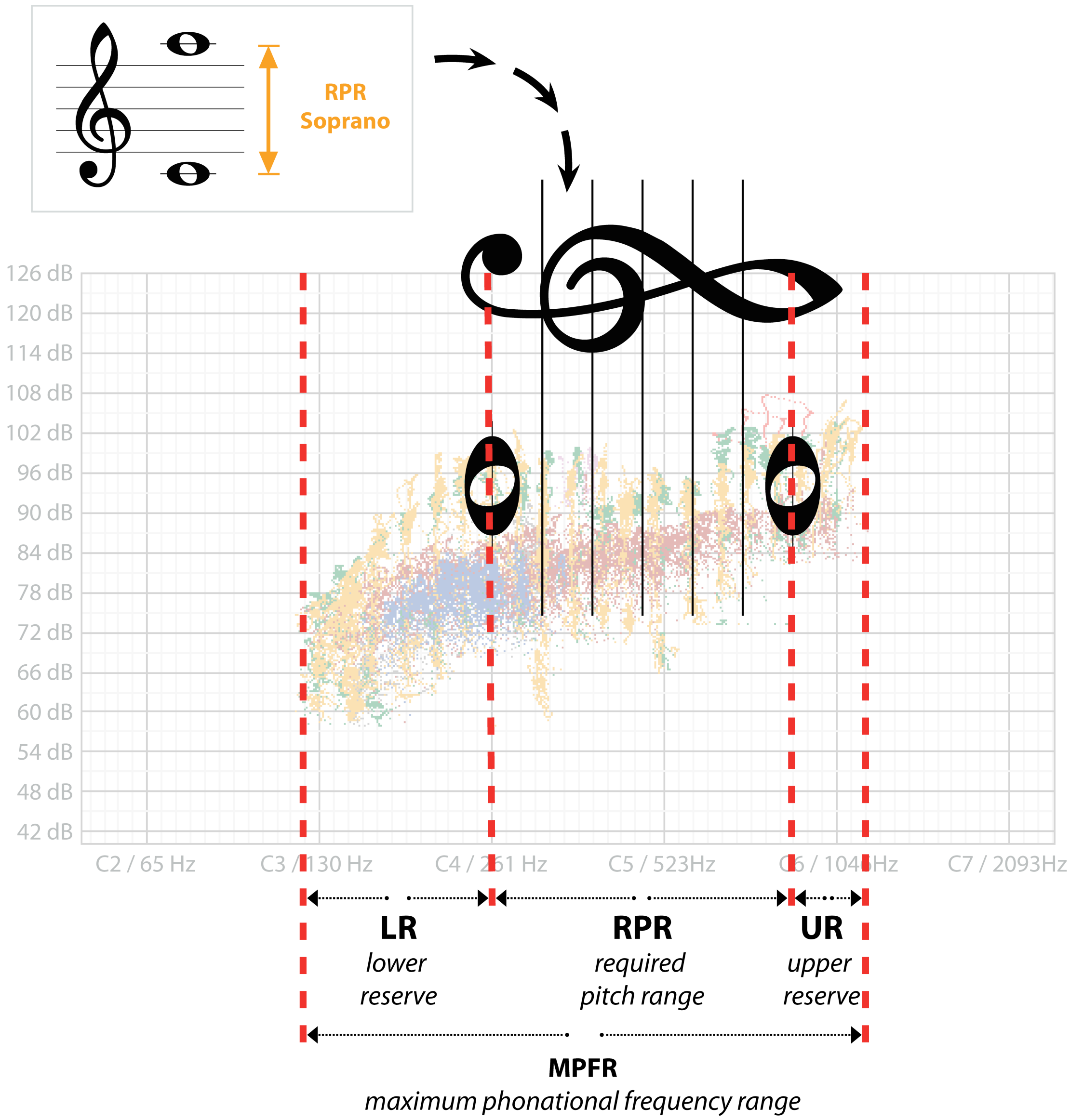

Figure 1. Comparison of maximum phonational frequency range (MPFR – data taken from an amateur choir singer's voice range profile) and required pitch range (RPR) for a soprano. RPR values have been chosen according to *the New Harvard Dictionary of Music* (1986). The upper reserve (UR) is determined by expressing the difference between the upper boundary of the singer's MPFR and the upper boundary of the RPR in semitones. The lower reserve (LR) is determined by comparing the lower boundary of the RPR to the lower boundary of the MPFR.

Results

Voice Range Data

Table 3 presents MPFR, RPR, LR, UR and TS data, and vocal health assessment for all participants.

Table 3. *Participant Results*

Participant	MPFR		RPR	LR (ST)	UR (ST)	TS	Voc. Health Assessment
AH Soprano 69y	F#3 - E6	34 ST	C4 - A5	6	7	-0.5	A
KB Soprano 54y	E3 - C#6	33 ST	C4 - A5	8	4	2	A
PZ Soprano 48y	C#3 - A5	32 ST	C4 - A5	11	0	5.5	B
ZO Soprano 74y	B2 - Eb6	40 ST	C4 - A5	13	6	3.5	A
BM Soprano 37y	C#3 – Eb6	38 ST	C4 - A5	11	6	2.5	A
EF Soprano 42y	Eb3 - E6	37 ST	C4 - A5	9	7	1	B
DN Mezzo-Soprano 33y	F3 – A6	40 ST	A3 - F5	4	16	-6	B
CL Mezzo-Soprano 70y	E3 – C6	32 ST	A3 - F5	5	7	-1	B
SB Alto 51y	C3 – C#6	37 ST	F3 - D5	5	11	-3	B
GE Alto 47y	Eb3 - Bb5	31 ST	F3 - D5	2	8	-3	B
RO Alto 35y	C#3 – C#6	36 ST	F3 - D5	4	11	-3.5	B
HP Alto 60y	D3 – D6	36 ST	F3 - D5	3	12	-4.5	B
WF Alto 61y	D3 – C#6	35 ST	F3 - D5	3	11	-4	B
MD Alto 33y	C3 – G6	43 ST	F3 - D5	5	17	-6	B
AB Alto 26y	Eb3 – G6	40 ST	F3 - D5	2	17	-7.5	B
JK Tenor 49y	E2 - A5	41 ST	B2 - G4	7	14	-3.5	B
FO Tenor 37y	D2 - A5	43 ST	B2 - G4	9	14	-2.5	A
FF Tenor 61y	Eb2 – Ab5	41 ST	B2 - G4	8	13	-2.5	B
AK Bass 58y	C2 - C#5	37 ST	E2 - C4	4	13	-4.5	B
WS Bass 39y	C#2 – Bb5	45 ST	E2 - C4	3	22	-9.5	B
RJ Bass 59y	B1 - Eb5	40 ST	E2 - C4	5	15	-5	A
Averages		***37.7 ST ± 3.95***		***6.0 ST ± 3.17***	***11.0 ST ± 5.19***	***-2.48 ± 3.75***	

Note: physiological maximum phonational frequency range (MPFR), expressed in pitch range and semitones; required singing fundamental frequency range (RPR) in semitones; lower reserve (LR) in semitones; upper reserve (UR) in semitones; tessitura shift (TS) in semitones, rounded to one decimal. A = symptoms that do not indicate clinical evaluation; B = symptoms that indicate clinical evaluation

As indicted by Figure 2, the sopranos had, on average, a greater LR than UL, whereas all participants of all other voice classes had a greater UR than LR.

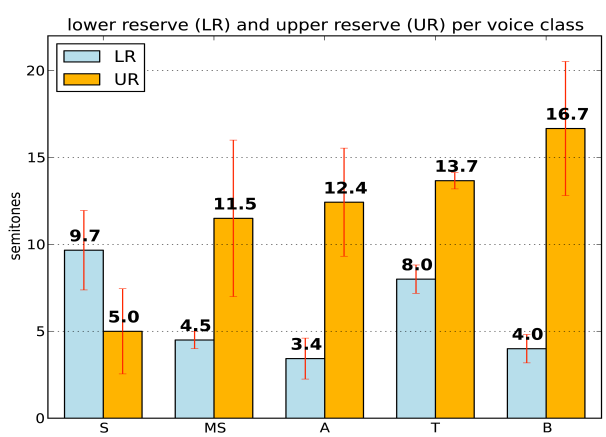

Figure 2. Lower reserve (LR) and upper reserve (UR), averaged per voice class

As Figure 3 shows, this finding was reflected by the TS data, which were positive for all but one soprano, but negative for all other participants.

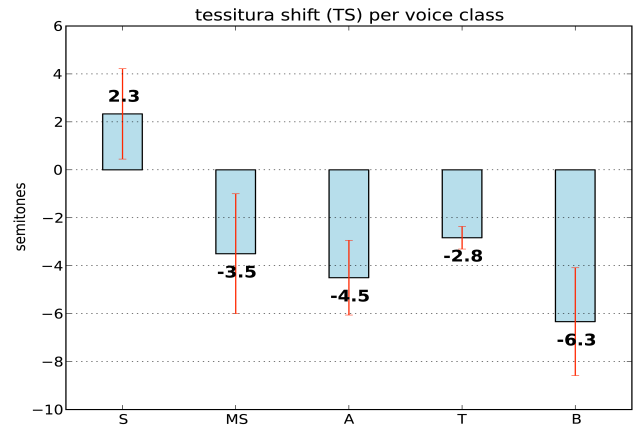

Figure 3: Tessitura shift (TS), averaged per voice class

The mean TS values were significantly different for the various voice classes ($p < 0.001$). Tukey's honest significance test showed that the TS values for sopranos were significantly different from those of all other voice classes ($p < 0.01$ for comparisons against alto and bass, $p < 0.05$ for comparisons against mezzo-soprano and tenor). No significant differences of mean TS were found for comparisons between other voice categories.

Voice status questionnaire

Based on the questionnaire data, only 6 (4 sopranos, 1 tenor and 1 bass) out of 21 participants were rated to have no symptoms that would indicate clinical evaluation. The other 15 singers were rated to have symptoms that indicate clinical evaluation (See Table 1). The average TS values grouped by vocal health assessment were 0 ± 3.29 (vocal health assessment: A) and -3.48 ± 3.54 (vocal health assessment: B). Nearly significant differences ($p = 0.053$) were found for the TS means, as grouped per vocal health assessment.

Discussion

The data collected in this study show that on average the participants have a rather large maximum phonation frequency range (MPFR), which exceeds their required pitch range (RPR) by an average of 11 semitones. All singers were able to physiologically produce all notes that were required as per their RPR, but in some cases only just. Extreme cases were soprano PZ who had no upper reserve at all (suggesting that she effectively sings at the absolute upper end of her physiological voice range), and alto AB who had an impressive upper reserve of 1.5 octaves, but a lower reserve of only 2 semitones (suggesting that she sings at pitches close to the lower end of her voice range). In these extreme cases, a change of voice class might be considered.

All singers except the sopranos had more upper reserve than lower reserve, which was reflected by negative tessitura shift (TS) values of all but one soprano. Overall, these data suggest that the sopranos tend to sing in the upper part of their physiologically available pitch range, whereas the singers in all the other voice classes showed tendencies to employ the lower ends of their voice ranges. The outstandingly high UR values of some altos, for instance, might be an indication to recommend the re-assignment of those singers to the soprano section, in order to use the full

Choice of voice class

It can be speculated that further factors influence the choice of voice class in this amateur choir, the most prominent certainly being the singers' timbre. Also, it is well known among choir directors that some "physiological altos" with a limited upper range tend to end up in the soprano section, because they are only able to sing the melody line, which is usually assigned to the soprano section in a mixed sex choir arrangement. On the other hand, musically talented sopranos are assigned to the alto section for the reverse reason. Singers might also choose a particular voice class due to personal relations to other singers. Such decisions are often made once, and are never revisited. Singing technique (or rather the lack thereof) might also influence these decisions, e.g., when singers avoid singing pitches around register breaks. Finally, preferences of music listening could influence habitual singing. Because the tessitura of a female singing in contemporary commercial music tends to lie within the range covered by chest register, young female choir singers, especially, might - in copying their role models - be inclined to choose the alto section in a choir.

Physiologic Pitch Range vs. Required Tone Range, Training Effect

The measured MPFR data were well within the expected ranges (Baken & Orlikoff, 2000). All participants were able to produce all pitches as defined by the RPR of their particular voice class. However, based on experience when working with amateur choirs, we speculate that untrained singers might run into technical difficulties when they sing at the top of the MPFR. Common sense would indicate that there should be some "safety margin" at the extreme regions of the voice range.

When applying the calculations of UR and LR we find an average UR of 5.3 and an average LR of 10.3 semitones for highly trained professional opera singers when performing "their best audition aria with lyrics"; and an average UR of 1.2; average LR of 2.92 for a series of *messa di voce* exercises spanning the singers' pitch range. It is not far-fetched to conjecture that for amateur choir singers without formal voice training the difference between the physiologically possible range of fundamental frequencies and the optimal tessitura should be equal, if not greater. In other words, amateur singers should have the same, if not larger, upper and lower reserves.

In this context, it is worth investigating whether vocal training does, if at all, increase the physiologically possible range of fundamental frequencies (MPFR). The investigations made by Awan (1991) and LeBorgne and Weinrich (2002) report increase of MPFR as a function of vocal training when measuring the "musical" voice range. Awan, on the other hand, points out that Colton and Hollien (1972) did not find differences in MPFR when comparing trained and untrained participants. Sulter, Schutte, and Miller (1995) report a significant difference of MPFR (4.8 semitones) for female trained singers (as opposed to untrained singers), the increase at the top range being an average 1.3 semitones. Their requirements for being considered a trained singer was a minimum of two years of "singing in a choir that conducted rehearsals with a minimum frequency of once a week." Mürbe, Sundberg, Iwarsson, Pabst, and Hofmann (1999) report, "the lower limit of the pitch range was lowered in 9 singers, and 6 of the 10 female singers increased their upper limit" after music conservatory singing education of 4–5 years. Overall, these reports suggest that some form of voice training is likely to enlarge the MPFR, and consequently also increases the upper and/or lower reserves of amateur choir singers.

According to the vocal health questionnaire evaluation performed as part of this study, a surprising 71% of the investigated singers reported symptoms that indicated further examination. Interestingly, four of the six participants without reported symptoms were sopranos, three of whom had a positive tessitura shift value. A possible interpretation of these facts might be that these singers sang the higher-pitched soprano parts, because they could do so without health complaints.

One could further speculate that proper singing technique and the absence of factors that would cause (slight) chronic voice problems allow these sopranos to sing their part. However, other interpretations, such as the possibility that these four sopranos simply had a higher threshold for reporting vocal health issues, are equally possible. The only conclusion that can be drawn in this respect is that self-reported questionnaire data are not sufficient to assess vocal health status. This possibility may suggest a need for in-depth assessments of the vocal health status of amateur singers with established clinical protocols (e.g. Dejonckere, et al., 2001), which, to the best of our knowledge, have not yet been attempted for entire amateur choirs.

Limitations of This Study

Several potentially limiting factors should be taken into account when considering the findings of this investigation:

- In this pilot study we investigated only one choir. Thus the results should not be generalized.
- Due to the lack of consistent definitions of RPR, we had to make an arbitrary choice of fundamental frequency ranges of voice classes (i.e., in this case, the *New Harvard Dictionary of Music,* 1986). Results of UL, LR and TS calculations may have been different if other base data were chosen.
- Due to the limited number of male participants, and because there has been doubt whether tone production in falsetto register should be accepted in male voices (Mürbe, et al., 1999), UR and RI data for male participants might not be entirely representative.
- Different elicitation tasks (e.g., sustained versus glissando tone productions) might influence the maximally measured fundamental frequency range (Coleman, 1993). The statistical data produced in this study were based on a rather small number of observations *(n* = 21). Results, even when showing statistical significance, should therefore be treated with caution.

Practical Applicability

Upper and lower reserve (UR and LR) are indicators for the degree voice usage in extreme frequency ranges. We can at this point, however, only maintain that upper and lower reserve (UR and LR respectively) should be zero or greater (negative reserve values indicating that some of the required notes cannot be sung by the singer). Empirical evaluations like the study of Lamarche et al. (2010) provide important baseline data that can be used as preliminary suggestions (when risking the assumption that "musical" phonations are also "healthy" ones). It might be the task of a future investigation to estimate, based on vocal health of choir singers, the recommended size (in semitones) of upper and lower reserve for amateur choir singing.

The tessitura shift (TS) is an indicator of the "alignment" of required pitch range (RPR) within the singer's physiologic voice range. Knowledge of the individual singer's tessitura shift is an important piece of information for choir directors when assessing whether a singer is assigned to the proper voice class.

In this pilot study, we presented an easily applicable method for quantitatively measuring the upper and lower pitch reserves (i.e., the difference between physiologic voice range and required singing fundamental frequency range, expressed in semitones) of amateur choir singers. We introduced the upper and lower reserve (UR and LR) as indicators for the degree of voice usage in extreme frequency ranges. We further introduced the tessitura shift (TS) as a measure of the balance between upper and lower reserve. Amateur choir singers' choice of voice class is a strategic decision that crucially influences the singers' phonatory behavior on a long-term basis. Upper reserve, lower reserve and tessitura shift might be useful indicators for making such a decision. ✪ IJRCS

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Compliance with Research Ethics
The authors certify (a) their ethical treatment of participants and (b) their safeguarding the confidentiality of participant information.

Declaration of Conflicting Interests
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Appendix

Questionnaire for VOICE Evaluation

A. GENERAL INFORMATION

Date of birth: ____________________ Profession: ____________________

Allergy, asthma: ____________________ Medication: ____________________

Infections: ____________________ Hearing problems:____________________

Smoker: ❑ Yes ❑ No ❑ ____________________ Alcohol: ____________________

B. SENSATION:

2a) Please tick:

How often do you feel... Except when ill

	Several times a day	Several times a week	Several times a month	Several times a year	Never
Effort when speaking/singing					
Lump in the throat					
Sensation of pressure					
Sensation of dryness					
Clearing the throat/Coughing					
Mucous obstruction					
Sensation of pain					

3) <u>**Voice Dysfunction:**</u>

	Several times a day	Several times a week	Several times a month	Several times a year	Never
Hoarseness					
Loss of voice					
Vocal fatigue					
Involuntary register break					

4) Do you have any experience as regards voice training / singing lessons? ❑ No ❑ Yes

→ If yes, please specify ____________________

5) Did you ever receive speech therapist treatment due to voice problems? ❑ No ❑ Yes

→ If so, why and how often/how long? ____________________

C. SINGING VOICE:

1) What is your voice class (voice category)? ____________________

2) Please judge your current state of voice? ____________________