Choral Phonetics - when vowels control the intonation

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Choral Phonetics is a voice and ear training system, allowing singers and choir conductors to reproducibly control intonation and homogeneity in the choir by means of the timbre of vowels. Timbre and intonation are directly connected. The article explains how the tone of voice, formants, and intonation relate to each other and how to use this knowledge practically in choral sound and vocal pedagogy.

Vowels influence the intonation by unconscious impressions of pitch that are already included in the timbre. Barely noticeable shifts in nuances of a vowel can determin whether or not a chord sounds pure.

This unconscious sound information comes from two harmonics which are highlighted in the vocal sound by the first and the second vowel formants (resonance tones in the vocal tract). Chorus singers can consciously learn to hear these harmonics and control them. This allows the conductor to gain controlled access to the timbre and offers a specific optimization of intonation and homogeneity.

Firstly, for a perfect homogeneous sound, formants within a voice group should be identical. Secondly, the second formant (especially in the male voices) should highlight these harmonics that fit into the musical context and occur at the same time as in the other voices.

This assumes that there is an awareness of the pitches of formants. The result is a new tool for the objective and reproducible control of timbre. As a result, homogeneity and pure intonation become controllable and even a factor in the composition of the choral sound.

The basis for this new use of vowels is vocal pedagogical elements of overtone singing. Singer and conductor thereby develop the following three capabilities:

1. A basic understanding of the relationship between the formants and intonation.
2. The hearing of the second formant as a pitch.
3. The fine motor skills to control the formant frequencies.

Singing tone - a chord of whistle sounds

In my experience, choir singers are often unaware that their singing tone consists of a chord of harmonics, which when singled out, resemble whistle sounds (pure tones). These chords always have the same structure and consist of the intervals of the natural overtone series: Octave, fifth, fourth, major third, minor third, etc. Our hearing does not comprehend this chord and processes it instead to a tone with pitch and timbre.

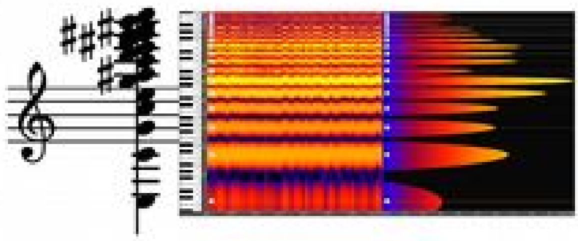

Figure 1: The first 16 harmonics of the chord, which is heard when singing a baritone C3. The chord goes further up, even over the threshold of 16,000 Hz. In this context, however, only the harmonics up to D7 are relevant.

We do not perceive the chord, because the brain has recognized since primeval times that its harmonics derive from a single sound source. The tone contains information about the source of the sound, which were more important for survival than the individual harmonics. The brain does not focus on the overtones initially; therefore we must train it by the aligning of focus in our hearing.

Timbre = volume distribution

The individual harmonics have different volume levels. The pattern of distribution of the volume produces the timbre: both the vowel and the personal timbre, allowing us to recognize individual voices. Our hearing is mainly focused on the distinction of these volume relationships in chords of harmonics (much better than by the distinction of pitches).

The volume distribution is generated by resonances in the vocal tract, also called formants. Hereafter, the terms formant and resonance frequency are used synonymously (criticism of the term formant cf. Wolfe (Wolfe 2009)). The lower three resonance tones are important for vocals and speech. There are more resonance frequencies, but only the lower three are deliberately controlled. The other resonances shape the individual sound. For German vowels only the first two resonant tones are of importance.

The frequencies of the vocal formants are variable depending on the tongue, lips, jaw and larynx position up to more than one octave. The flexibility of its form and thus its resonance frequencies and timbres, distinguishes the vocal tract from inflexibly built musical instruments.

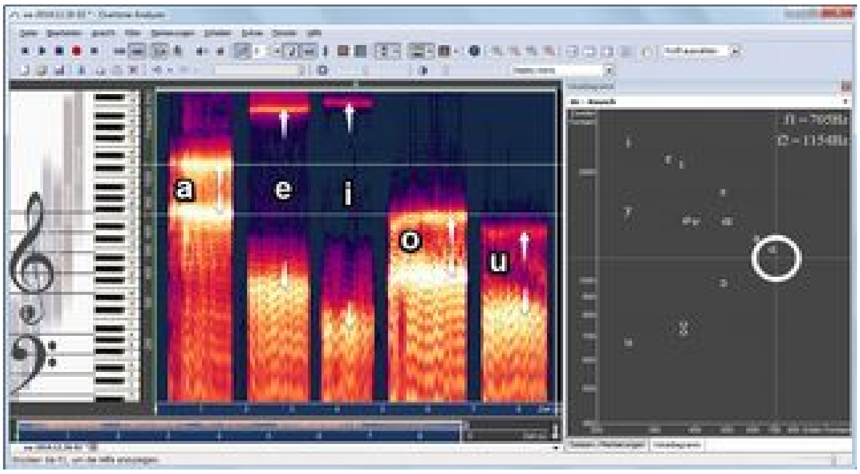

Figure 2: Formants demonstrated with "ingressive vocal fry", a creaking sound, produced by phonation during inhalation. This sound indicates the location and the tone character of the formants most clearly. The horizontal lines look almost like harmonics and can actually be perceived as pitch. They are but the noise components filtered by resonance from the noise.

Formants perceived as tones

Formants are not consciously perceived, just as the harmonics chords of voice sounds are not. Yet they are tones within the context that they cause pitch perception, and you can easily learn to hear them.

Under certain conditions, especially with the second formant being noticeable as a pitch, this is when the sound source is a noise and the formant frequency changes are made in small increments. The pitch perception is not immediately set. As long as the resonances remain stationary, our trained language centre first attempts detection of a vowel. But by moving one of the formants in musical intervals, it then becomes clear that they are not perceived as vowels, but as a melody. This works especially well with the 2nd formant, which has the strongest influence on a subconscious level.

The vowel perception is widely flexible, so that little pitch shifts of the formants cause only barely perceived changes in nuances. For some vowels the resonances can be shifted by as much as a fifth and still be recognizes as the same vowel. If you turn on your pitch perception, though, such a change in timbre turns into a clearly audible musical interval.

This change in perception is one of the objectives of choral phonetics. The shift of perception is different individually, de-

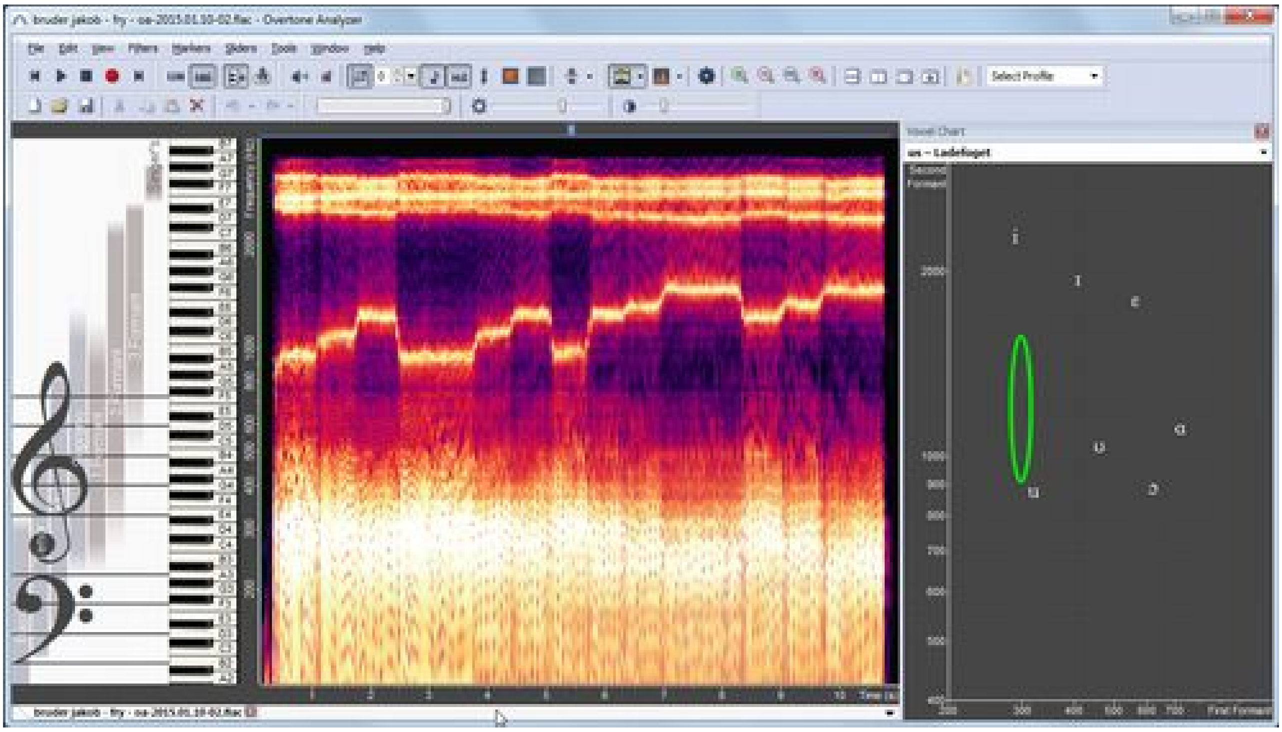

Figure 3: The formant spectrum of the creaking voice. I started with an undefined vowel at the bottom of the marked ovals in the vowel chart (right side of the picture). Then I vary solely the 2nd formant in the marked area. The pitches are to the tune of "Frère Jacques", and you hear this tune then instead of vowels. This is a way to teach the brain how to listen to formant pitches. The fact that the vowels used are unusual helps to enhance the perception of a melody instead of vowels.

pending on how the brain processes sound (Schneider u. a. 2005).

Harmonics meet the formants chord

The vocal sound is a combination of resonance tones and the chord of harmonics. Harmonics close to the resonant frequencies appear louder than the others. In contrast to speech, the pitch and therefore the harmonics chord during singing are held constantly for some time.

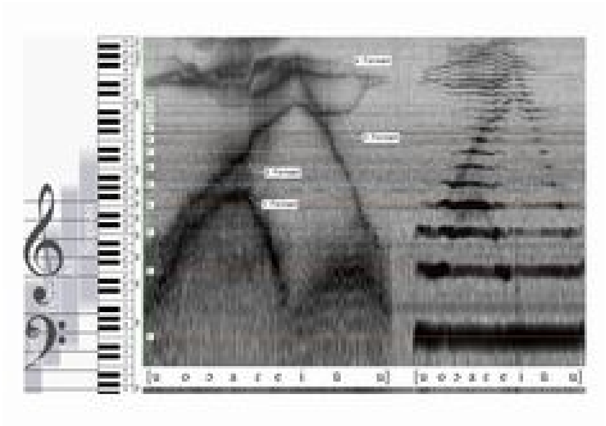

Figure 4: To the left in the picture, you see the formant spectrum of some German vowels and vowel transitions. To the right, you see how the track of the formants is reflected in the sound spectrum of the singing tones. You can also see that the formants have no effect between the harmonics, because there is no sound energy to activate the resonance.

Singers, due to reasons of efficiency, must ensure that the formants match frequencies of the harmonics as accurately as possible. The vowel fidelity is subordinated to efficiency in singing. This distinguishes singing phonetics essentially from speaking phonetics (Coffin 1980).

Necessarily, only a special selection of vowels is useful for singing sound. The vocal sound spectrum provides only overtones with harmonic frequencies. Therefore only vowels having a harmonic formant spectrum meet the agenda for efficiency. (To my knowledge such a presentation has not been previously published). The following chart is a compilation of vowels with harmonic formant intervals.

The skill to control the 2nd formant, as demonstrated in figure 3, can now be used for the vocal coloring to choose harmonics, which on one hand does not alienate the vowel too much, yet takes into account the musical context as shown in the following example. In addition, it is now easy, as a byproduct, to homogenize the timbre within a voice group.

Practical example: Amen

The following example demonstrates how these principles are applied in the actual work of the choir. The word Amen is sung as a four-part D-major chord.

As soon as the bass in the third variant (bar 6) points out the 10th harmonic (natural major third), a striking change of intonation in the alto voice can be detected. Alto tunes down to the natural third (14 cents below the equal temperament). The 10th harmonic F6# in the bass voice, is identical to the 4th harmonic of F4# in alto. Intuitively, the altos adjust their keynote to the natural third to avoid beats (assuming chamber choir qualities of the singers). The chord is pure. At the same time, sopranos and altos create a pure minor third with all their harmonics and thus produce D2 as the difference tone, one octave below the bass. The entire chord fills the space, sounding full and stable.

The second variant (bar 4) produces a very stable fifth. At exactly the same formant position (same pronunciation) in bass, tenor and soprano, all three voices lift the same overtone E6, 9th harmonic in the bass, 6th harmonic in the tenor, 3rd harmonic in the soprano.

Freedoms of the 2nd Formants in the syllable men

The syllable 'men' is spoken with the neutral vowel ə, the Schwa. In singing, depending on the fundamental, several nuances of the syllable are possible. Basses can sing 'men' on a D3 in a way that either the 8th, 9th or 10th harmonic D6, E6, F6# sounds off; all without significantly changing the vowel character.

In vocal fry technique the 2nd formants can clearly be heard as pitches. In the sung version, listeners without overtone listening training describe the differences rather as a slight brighte-

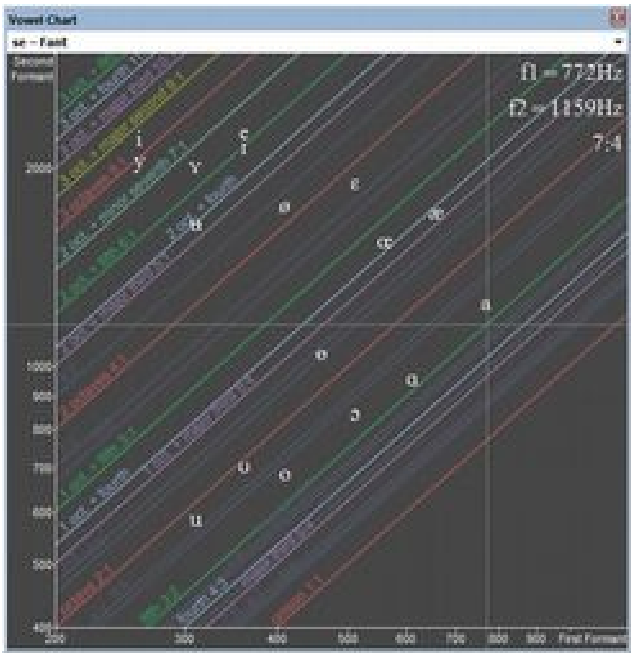

Figure 5: The diagram is a representation of the complete singing phonetics: Only vowels, with first and second formant simultaneously matching harmonics of a singing tone, are of optimal sound efficiency. It was surprising to find that for the majority of vowels the formants are more than an octave apart, and thus are of second grade harmonicity (no neighboring harmonics reinforced).

Figure 6: Bass brightens up the syllable 'men' a bit with each repetition of Amen. This is achieved by setting the 2nd formant on the 8th, 9th or 10th harmonic respectively.

ning of the vowel, or perceive no change of the vowel at all. Formants are more difficult to hear with sound than with noise. Overtone-trained ears, however, hear the harmonics highlighted by formants clearly and distinguish the vowel qualities just as differentiated, as they differentiate the notes D3, E3 and F3#.

Minor chords sound better without the 10th harmonic

In a minor chord the 10th harmonic of the bass must be avoided, otherwise the alto is unable to keep the minor third. A minor third in alto together with the 10th harmonic in bass sounds like wrongly intoned, even if all tones are sung correctly.

Special effects can be created, when bass enhances the 9th harmonic (major ninth) as a kind of suspended ninth, which in the 8th harmonic (octave) resolves to an almost medieval quiet chord.

All these effects are not consciously perceived by the listener, but have a great influence on the effects of the music. The choristers must however, perceive the harmonic reinforcement consciously to control these effects.

Vowels with ten times more nuances

The ways of controlling choral vowels, are limited in traditional voice training to the singer's skills in implementing the vowel conception of the conductor. Usually that happens through imitation or through imagery descriptions such as "light", "smiling", or by word comparisons. In professional choirs the experience plays a key role, in which the singers intuitively select vowels that match well with each other and are in sync with the musical context. The better a choir masters this, the better is the choir sound.

With the help of choral phonetics, the vowels are divided in up to 10 times more reproducible nuances. The choral sound reaches a completely new level of control. The IPA vowel chart is not suitable to describe this precision, therefore I will soon propose a new IPA chart, which will use pitch deviation from 'prototype vowels' as the basis for singing phonetics.

Practical exercise of formants control

A complete guide to the practice of the formants control would be beyond the scope of this article. In order to receive an impression of how the method works, and to experience how quickly it can be learned, I provide an exercise here that trains the tongue and lip movements that control the second formant solely.

As an overtone singer, I learned to regulate the first three formants independently. This is the basis of a singing technique (Saus 2004), wherein one singer seemingly sings two tones simultaneously by merging two resonance frequencies on the

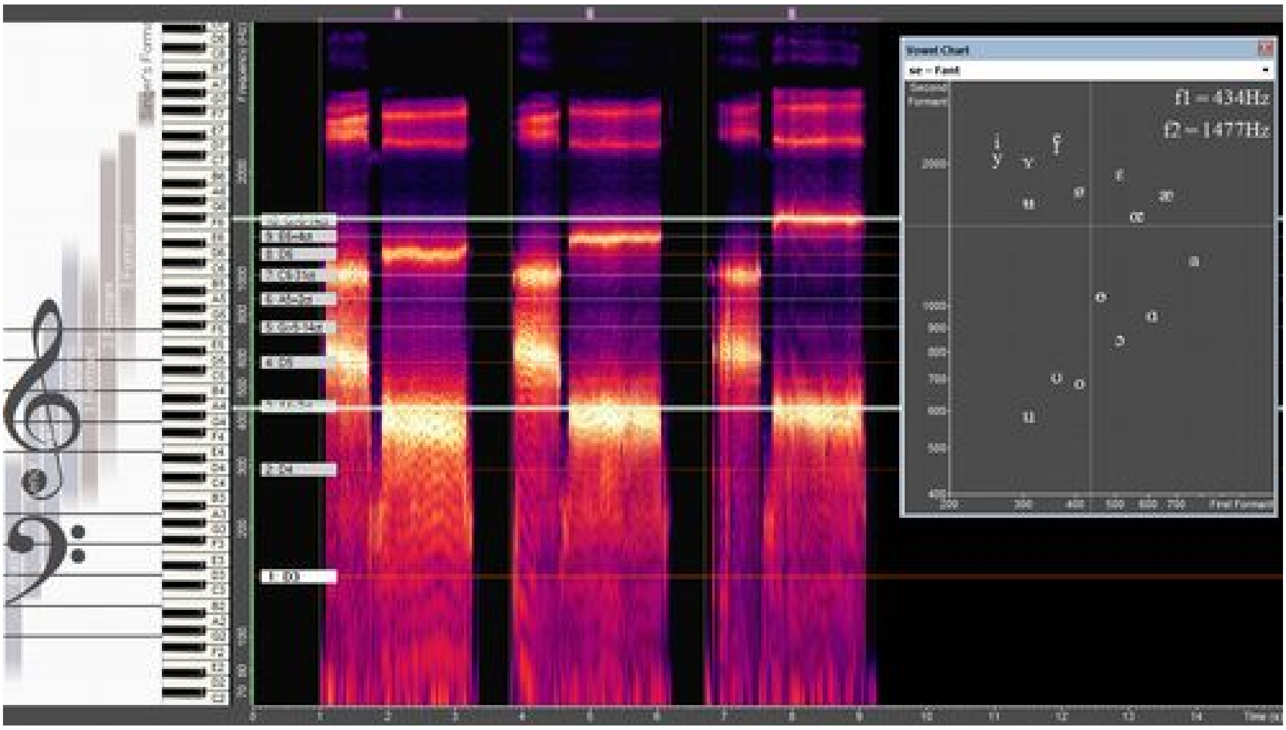

Figure 7: Formants recorded with ingressive vocal fry technique (hence voiceless). The harmonics of the fundamental D3 are drawn as lines. On the right side you see the location of the formants of the third 'men' in the vowel chart.

same frequency and thus creating a double resonator, highlighting overtones substantially in the overall sound. It is sufficient for choristers to only control the second formant, because this conveys the predominant pitch impression. The second formant is regulated by the epiglottis and the root of the tongue.

Exercise: An exclusive movement of second formants is obtained, by limiting yourself to the vowel sequence I-Y-U (English 'you') or U-Y-I (French 'oui' or English 'we') and by keeping the front part of the tongue, jaw and lips motionless.

Allow the tongue to hang loosely out of your mouth, resting on the lower lip. Then sing the English 'you' and French 'oui' in slow motion, without moving the front part of the tongue nor the lips. The result is sometimes perceived as a slight Saxony accent. It is important that you include the unknown vowels between I and U (i-y-ɨ-ʉ-ɯ-u) while in slow motion. You can hear softly a series of overtones. The second formant is moved up and down in the vowel chart and reinforces one overtone after another, while the first formant remains unmoved. The exercise sharpens the ear as well as the motor skills for the corresponding fine motion of the pharynx tongue and the epiglottis.

After one or two hours of practice, experienced singers can already position the second formant precisely on a semitone.

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