The Diminished Vowel Space in Classical Singing and the Tug-of-War between “Speech-true” and Modified Vowel Qualities

A Model to Help Singers Achieve a Better Pronunciation of Vowel Phonemes and Allophones in Singing?

Wencke Ophaug

Good voice quality and good diction are often contradictory. This basically concerns vowels. In classical singing, vowels are often modified in their quality from speech, to make the voice function better as a musical instrument, often to such an extent that vowel identification is impossible and fine detail differences in quality regarding one and the same vowel phoneme in different languages may be neutralized. Many attempts have been made to try to understand why and how vowels need to be modified from a musical point of view; not many attempts have been made from a linguistic point of view to understand the effects of this modification on text delivery and intelligibility.

The aim of this article is threefold. I intend to show and explain why there seems to be a smaller phonetic vowel space in classical singing as opposed to normal speech. I also question how vowels are reorganized from speech to singing in order to fit into this new area. And I attempt to present an explanatory model with some predictable rules and give some useful guidelines to help singers improve their diction in singing in general and to better target the correct phonetic quality in any foreign language they want to perform in particular.

I base my presentation on results from my dissertation back in 1999, which bears the title “Vowel Migration and Equalization in Classical Singing”, and on my experience in the years thereafter, tutoring students of classical singing in the phonetics of singing.

Introduction

Modifying vowels in classical singing is immensely important. When vowels are modified in a correct way, singers will have better resonance across their ranges, more carrying power, better control over dynamics, more ease in upper range singing, and a better blend. But singing is also about text delivery, and although it is true that consonants surrounding vowels are more important for word and text intelligibility than the vowels themselves, it may become difficult to identify words when the modified vowel cannot be identified as the vowel phoneme it is meant to represent.

Vowel modification is used in all voice categories and in all ranges. No vowels are really sung the way they are spoken. But the degree of modification is higher in high voices and in upper ranges. As a result of that, sopranos and tenors may be very difficult to understand; basses and baritones have a more intelligible pronunciation. It is often argued that it is easier to have a native-like pronunciation when you sing a language than when you speak it, due to vowel modification. This is true to a certain degree, but dependent on how much you need to modify. We can often tell whether the singer we are listening to is native or not, also when the singer is a soprano. A singer, no matter what voice category or what range needs to focus on good and intelligible diction and native-true vowel qualities. How important is this, and how can a singer manage it? I asked the famous Welsh baritone singer, Bryn Terfel, who is known for his
good diction and also for his native-like pronunciation in any language he chooses to perform in. This is his answer:

I adamantly believe that unless people can understand what you are saying when you are singing, then you are cheating the audience. There is nothing more annoying than listening to someone sing and not even being able to work out what language they are singing in, because they concentrate so little on diction and so much on producing beautiful sounds. (...) Because of my firm belief in the importance of words I do make every effort to match the correct phonetic quality in whichever language I sing.²

But, as already mentioned, it is more difficult to have a clear diction if you are a soprano. According to Scotto di Carla, a bass or baritone singer might achieve about 100 % text intelligibility if they are good, whereas a coloratura soprano probably will not achieve more than 20 %, no matter how much she focuses on good diction.³

But good diction is more than producing clear and distinguishable consonants and vowel phonemes; it is also about matching the right phonetic quality of all the sounds in a given language, at least in order to sound native. This is a bigger challenge for low voices than for high voices. A soprano often does not need to focus on various phonetic variations of e-vowels in different languages, when she, at least on top notes, modifies any intended vowel into something sounding like an /a/.

**What is vowel modification?**

It is important to distinguish between voice timbre on the one hand and voice quality/color on the other. Voice timbre embraces all formants in the production of a vowel and has to do with the overall quality of the voice, whereas vowel quality or color is linked to the three lowest formants, the ones that make us able to identify a vowel as a vowel phoneme different from other vowel phonemes, or enable us to perceive the fine phonetic differences in quality between languages concerning the same vowel phoneme. When formant frequencies are shifted up or down along the frequency scale, not any longer located where they are in speech, for musical reasons, we have a modified vowel. Any change in one formant region will lead to a change in the other formant regions; it is not possible to change only the timbre, or only the vowel quality. When higher formants are being manipulated for musical reasons, also lower formants will also be affected, and vowel identification will become poorer.

**What are formants and how are they linked to articulation?**

It is useful for singers to be familiar with phonetics in general, and especially to know and understand the concept of the phonetic vowel space (see figure 1). A vowel space is normally understood as a combination of an articulatory and auditory mapping of vowels in a two-dimensional space. Vowels are placed in different areas of this space, based on how they are articulated and how they are perceived. It is first of all the vertical and horizontal location of the highest point of the tongue body that decides the location. Lip position (rounded, unrounded, spread lips) can not be directly illustrated in this space, but lip position is connected to the idea of a vowel being perceived as darker or brighter, and a rounded vowel will be located more to the right in the vowel space than an unrounded equivalent, as vowel qualities are darker the further back in the space they are located.
I base my further presentation on the assumption that the reader is familiar with this concept, and if not, will read up on the topic.

Vowels can also be described acoustically by means of formant frequencies. And it is possible to put the two most important of them, F1 and F2, into a combined articulatory/auditory and acoustic vowel space. Yet, for the acoustic space, we need to use a diagram which has been flipped and mirrored diagonally, so that zero is placed in the upper right corner. The x-axis represents the F1 frequency range; F1 moving downward with increasing frequency - and the y-axis represents the F2 frequency range; F2 moving to the left with increasing frequency. The coordinates of these two lower formants, the location of an acoustic vowel so to speak, will thus be in a relatively good accordance with the location of the articulatory placement of the same vowel, as shown in figure 2.

So what are formants? Let us stick to speech first. When we generate voice (phonation) with the vocal folds, these periodically vibrate in a complex way, producing fundamental pitch (f0) and partials (in acoustics, or overtones/harmonics in music) at the integer multiples of the fundamental frequency. Since the partials are distributed at the multiples of f0, the distance between them will increase as pitch rises. When the source signal (f0 and all partials) is sent through the oral cavity, it is formed by the shape of the tongue, jaw position, lip posture, and the vertical position of the larynx. This means that some overtones are enhanced, while others are weakened in accordance with the resonance characteristics of that specific articulation. The strong partials are grouped around a highest frequency point, called formant frequency. The three lowest formants, the ones associated with vowel quality, are linked to the articulators in the following way:

- F1 is connected to jaw opening and vertical tongue position. Lowering the jaw and/or the tongue will increase the F1 value.
- F2 depends strongly on the length of the vocal tube. The values get lower when the tube is longer. Both lip protrusion (labialization) and lowering the larynx will greatly lower this formant frequency.
- F3 is primarily connected to lip rounding. The more distinct the lip rounding, the lower F3 will be.

In speech the articulators are very active in shaping different vowel sounds. Larynx position has until recently not been part of an articulatory description of spoken vowels, but we know now that this is an important parameter. The larynx typically moves upward (making the tube shorter, together with the spread lips) for an /i/, and moves downward for an /u/. A ventriloquist needs to have a stabilized mouth position, so that it is impossible to see that he is speaking. To make a clear difference between /i/ and /u/, or /e/ and /ø/, he will exaggerate the use of larynx height instead, raising it efficiently for the unrounded vowels, lowering it considerably for the rounded vowels. He will, of course, need a scarf or a turtleneck to hide his very active larynx. Vowels in speech are normally not very loud. If we pronounce them separately, all with the same pitch and the same air pressure (difficult to control), they will have different loudness and carrying power, /a/ is the loudest vowel, /i/ the softest. Arranged along a sonority range, low vowels will be louder than low-mid vowels, low-mid vowels louder than close-mid vowels and close-mid vowels louder than close vowels. When we speak, the sonority differences do not matter much. In singing, steady volume from one vowel to the next in a sung phrase may be crucial. In singing, vowels also often need to be very loud, to be heard across an instrumental accompaniment. In normal speech, we do not
need vowels to be that loud unless we shout. In shouting, vowels are often modified too. Try to shout “bead” as loud as you can. It is likely to sound more like “bed”.

Let’s us now look at the frequency pattern of a given vowel and see what formants look like in speech (figure 3). The fundamental frequency average of a male voice lies around 100 Hz. There will be plenty of partials in the voice, all with a distance of 100 Hz, and formants are easily shaped. In a female voice, which has a fundamental frequency average about one octave higher (a doubling of frequency) - a fundamental of 200 Hz - there will be a distance of 200 Hz between the partials. But also in a female voice there are plenty of partials along the scale for formants to be shaped; see figure 3.

Formant-shaping in a high soprano voice, is yet a different matter. When a soprano sings on the famous high C, the tone will have a fundamental frequency of about 1000 Hz, and the distance between all the overtones will also be 1000 Hz. In other words, there will be only six partials in a frequency range from 0-6000 Hz. There is thus a mismatch between the number of partials and their frequency positions on the one hand, and the vocal tract’s resonance abilities on the other. Partials cannot be enhanced if they do not fit the natural resonance power of the vocal tract. Sopranos have very few partials to produce formants in the upper voice register, and it is difficult to produce identifiable vowel phonemes, see figure 4.

Vowel modification in classical singing is a constant and crucial technique. There are two main reasons for this, which we will focus on below: the need to enhance the carrying power of the voice in general and the need to have better control over dynamics.

**Voice techniques and vowel modification**

So, in order to have a loud and a beautiful voice, classically trained singers seek to use vocal tract shapes that have resonance characteristics that match the fundamental frequency and its harmonics of the given note they are singing. This is not an easy task, it does not come naturally to all singers, and most of them will have to learn how to do this in a proper manner. But how can they be guided?

Over the years there have been many attempts to understand the nature of vowel modification in singing. Over thirty years ago, Coffin presented his pedagogical “favorable vowel chart”, followed up by a second edition ten years later, then presented as a “chromatic vowel chart for voice building and tone placing” Coffin’s pedagogical presentation of the pitch-vowel interaction was based on a linear source-filter theory of vowels. This idea has been replaced by a more complex non-linear source-filter theory. As Titze states, the old linear theory was about boosting any harmonic to enhance the voice, the new theory of pitch-vowel interaction is often about avoiding the formants, since the selective boosting of some harmonics may create irregularity of the vocal fold pattern. In addition, it will certainly have a negative effect on the dynamics, if a singer goes from one vowel to the next in a phrase, using a vowel modification that only takes into consideration a means to enhance formants somewhere in the frequency range, and not take care of the dynamics of these vowels. Vowel modification thus goes hand in hand with equalization; a need to change and equalize adjacent vowels in a sung phrase so that they are both loud enough to be heard, but also equally loud if the dynamics of the phrase require them to be so. Titze presents a very clear picture of how complex and difficult this is:

Chasing favorable vowels, as Coffin called them, on an ascending pitch scale is like walking up a tall mountain that has multiple peaks and valleys along the way. You stay on the upslopes and try
to leap over the valleys as quickly and effectively as possible. The difficulty is that if “you” are the harmonic, all your family members (the other harmonics) have to do the same thing in lock step. You walk in a row, separated by a constant distance, but the peaks and valleys are not equally apart. According to Sundberg and Ternström there are two main resonance techniques in classical singing. Sopranos use the so-called “tracking of the fundamental” on high-pitched tones. Male voices use the “singer’s formant”. Both techniques are efficient ways of enhancing the loudness of the voice substantially.

On high notes, a soprano must find an articulation that makes her fundamental frequency coincide with the first formant frequency (see figure 5) so that this frequency is enhanced. The “tracking of the fundamental” is a technique which has a lot in common with the above mentioned theory of Coffin. It certainly is about boosting one partial, but it is about boosting the fundamental frequency first of all. With increasing fundamental pitch, the soprano will lower the jaw accordingly and the close vowel /i/ will be perceived as /e/, then /æ/, and in the very high pitches all vowels will sound like /a/ or /ɒ/. According to an investigation made by Scotto di Carlo and Rutherford, 34 percent of all incorrectly identified soprano vowels were perceived as /a/ by the listeners.

The “singer’s formant” is a clustering of formants in the higher formant region (F3, F4, and F5) around 3000 Hz. This strong formant peak has a strong audibility due to the fact that the orchestra does not have much energy in this frequency region (figure 6). In addition, our ears are very sensitive to frequencies around 3000 Hz (Slethei). The voice gets dramatically louder when the singer’s formant is added. The creation of a strong “singer’s formant” is associated with a lowering of the larynx. A lowered and stabilized larynx is typical in classical singing, but in male voices it has the extra effect of being part of the creation of this special formant. Yet, a lowered larynx also has an effect on vowel quality and hence vowel identity. Since a lowering of the larynx means a lengthening of the vocal tract or tube, F2 decreases in frequency. /i/ will sound like /y/, /e/ like /ø/ and /e/ like /œ/.

The diminished vowel space

When we listen to classical singers we can tell that the overall quality of their voice is not only beautiful, but very often has a rounded and warm, but also open timbre. Singers may use a slight lip rounding to achieve the rounded effect, but the main reason for this timbre is probably the somewhat lowered and stabilized larynx. It can of course be a combination of both. This leads to a migration of front unrounded vowel phonemes in a direction to the right in the vowel space. Close vowels are as we have described, not very ideal for a loud voice, close vowels are often sung with a lower tongue position and a more open mouth position than their spoken counterparts. They are typically shifted down to the close-mid area, creating a more open timbre. In higher ranges, and especially in sopranos, the need to boost the fundamental and therefore to use more open vowels (with higher F1 to coincide with the fundamental), makes the vowel space loose more and more of the upper area as pitch rises.

This means that the upper area and the most frontal area of the vowel space is being less exploited in singing than in speech, or not at all, and we will have a diminished vowel space.
An obvious question then is: what happens to language? How do we re-locate vowel phonemes and allophones in this smaller vowel space? Are they moved in a way so that there is a relative distance between all of them corresponding to speech? Definitely not. That would cause all vowels to sound alienated. We know that this is not the case. Many vowels sound just fine in classical singing, from a linguistic point of view. They don’t seem to have been modified much at all. Some sound totally different in singing than in speech and very often they are confused with other vowel phonemes. Is there a pattern behind this? Can we predict which vowels in the vowel space will be modified, in what direction and to what degree? And is it possible to simplify matters so that it is possible to present a model of vowel modification that can be used for all voice categories and pitches? And can this model take into account not only the intra-language effect (vowel phonemes coming closer together, making vowel identification poorer), but also the inter-language effect (allophonic differences between languages concerning one and the same vowel phoneme becoming more alike or even neutralized, so that singing with a native pronunciation becomes an easier task)?

My idea is that there are two processes, one governing the modification process and the other governing the language; the need to stick to “speech-like” vowel qualities whenever possible.

The tug-of-war hypothesis

I chose to refer to the explanatory model as the “tug-of-war”-hypothesis. Depending on the particular quality of a vowel in speech, it will be in conflict with the musical demands to a greater or smaller degree, or perhaps not at all. A good singer strives to maintain a vowel quality as true (natural) to the spoken quality as possible and will abandon this goal only when musical demands are in conflict with it. The result of the musical act and the phonetic counter-act may be described in the following way: vowels that are peripheral in the vowel space will to a large degree be qualitatively subjected to musical demands (musical act), vowels that are relatively central will be in less need of being changed in singing. Generally speaking, the musical act can thus be said to force vowels to a more centralized position in the vowel space. This force will be substantial in the outer areas and decrease gradually towards the center. The phonetic counteract functions as a constant counter-factor. The vowel qualities of a given language will change from speech to singing only when their spoken quality is in conflict with musical demands, and they will remain unchanged when their spoken quality is not in conflict with these.

In my dissertation I tested this theory for the baritone voice only, and everything I present in the following chapter is related to this voice category.

The diminished vowel space in baritone singing and the re-location of vowels into this space

I used four professional baritone singers; two Norwegian, two German. All of them speak the standard of their language. They all showed a clear singer’s formant throughout their singing. They were asked to sing and recite (hereafter referred to as speech) a whole Lieder or song cycle in their own language. They performed this task in a low-reverberant room with no orchestral accompaniment. The three lower formants, F1, F2 and F3 of all tokens of long vowels in these cycles were measured.

Our point of departure was that a baritone singer uses a lowered and stabilized larynx throughout singing to create a boosting of formants in the higher formant region. The formant changes of this regarding the
three lower formants are expected to be: a rise in F3, since this formant needs to join together with F4 and F5 in singer’s formant cluster and a substantial decrease of F2, because of the prolonged vocal tract/tube.

In addition, singers are known to use a more open articulation of close vowels, both lowering the tongue and dropping the jaw to some extent and thus increasing the frequency of F1. Titze also comments on this: Note that the mouth (…) is more open for the singing /i/, approximating more of an /ɪ/ shape. We all know that singers tend to do this, especially with a rising pitch. We say it creates more space and produces more resonance.11

We will first of all discuss the results concerning F1 and F2 in the following. Figure 7 shows the results regarding one Norwegian singer (N1). The two subjects in each language showed relatively consistent migration of vowels. This made it possible to draw figure 8, which is a simplified version of figure 7, and much easier to interpret.

The results can be summed up as follows:

On a general basis, the results showed that the singers all used a diminished vowel space in singing as compared to speech. The reduction of the vowel space was first of all seen in that vowels in the upper part were moved downward and vowels in the left part were moved to the right. To some extent too vowels in the lower part were moved up and vowels in the back part were moved to the left.

Regarding the migration of the different vowel phonemes, we expected some vowels to move to a more centralized position in the vowel space than others. We anticipated that this force would be substantial in the outer areas and decrease gradually towards the center.

As for the intra-language (within each language) migration of vowels along the F2 scale, the results of the investigation were in accordance with our hypothesis:

For Norwegian: The vowel /iː/ made a large jump to the right, the /yː/ a somewhat smaller jump, whereas the /uː/ kept its original position. For German: the /iː/ had a very large decrease in F2, the /yː/ a somewhat smaller decrease. For both languages: the vowel /eː/ had a large decrease in F2, whereas the /œː/ only moved a little in that direction. In German the /ɛː/ moved towards /œː/ (short vowels not part of the investigation, however); the Norwegian /æː/ had a somewhat shorter move than the German /ɛː/.

Along the F1-line the results were in accordance with our expectation concerning the close vowels, but somewhat intriguing regarding the close-mid vowels. In both languages /iː/ showed a clear movement downwards, whereas /ɛː/ in both languages showed a relative constant location.

Regarding the results of inter-language (between languages) migration of vowels along the F2 scale, our hypothesis was verified.

The German /iː/ is known to be more forward than the Norwegian counterpart in speech. This was confirmed in our results in that the former showed higher F2 values than the latter. In singing, the German vowel showed a significantly larger F2-step down than did the Norwegian equivalent. In speech the Norwegian /yː/ has F2-values close to those of the Norwegian /iː/, whereas the German /yː/ has F2-values close to that of the Norwegian /uː/. The decrease of F2 was considerable for the sung /yː/ in Norwegian,
whereas the German sung /yː/ had a smaller decrease. The Norwegian /uː:/ did not move to any interesting extent.

The vowel /eː/ has far higher F2 values in spoken German than in Norwegian, and F2 showed a significantly larger decrease from speech to singing in the former than in the latter language, as expected. In both languages the frequency of F2 in /eː/ ended up in singing close to the F2 frequency of /øː/ in both languages.

Along the F1 scale the hypothesis was verified regarding the close vowels. /iː/, /yː/ and /uː/ in German and /iː/, /yː/ and /uː/ and /uː/ in Norwegian. The close vowels in German show a lower F1 frequency (a higher location in the vowel space) in speech than the Norwegian counterparts, and the former all showed a larger increase of this value (a lowering to a larger degree) when sung.

As for the close-mid vowels /eː/, /øː/ and /oː/ our hypothesis was not verified. The German versions of the close-mid vowels have considerably lower F1 values in speech than the Norwegian counterparts. The Norwegian close-mid vowel could actually be classified as open-mid (this is done in some presentations of Norwegian vowels). We therefore expected the German close-mid vowels to show a clear degree of F1-increase, moving in direction of the Norwegian counterpart. This was not the case. The German close-mid vowels stay more or less in the same F1 position in baritone singing as in speech.

We see from these results that there are intra-language and inter-language equalization processes in singing. We clearly see that some vowel phonemes come closer together in the vowel space, either in the horizontal dimension or the vertical one. We see which vowel phonemes in one language come closer and to what degree, and we see that this to a large degree is dependent on their location in speech. It is in other words possible to predict, at least to a certain extent, the direction and degree of vowel modification in a language, at least in a baritone voice. We also see that there is an inter-language equalization in singing. It is possible to predict to a certain degree which vowel phonemes will have a more similar quality in singing than in speech.

We did not find the expected rise in F2 in the German close-mid vowels. This could be interpreted as follows: In a baritone voice there is no need to increase F1 values below a certain point, possibly around the point where close-mid vowels are located. In higher voices, tenors or especially sopranos, we know that the migration process continues, with ascending F1-values along with an ascending pitch scale, all the way down to /a/.

What implications do our results have for a Norwegian baritone singer who wants to perfect his German pronunciation in singing? Here are some of them:

- He does not have to be concerned about /iː/ or /uː/. In singing these vowels sounds the same in both languages.
- He does not have to worry about the fact that /iː/ and /eː/ sound rounded and might be mistaken for the rounded counterparts /yː/ and /øː/. It is typical in singing and happens also in Norwegian.
- He does have to be worried about the open-closeness of close-mid vowels though. /eː/, /øː/ and /oː/ all need to have a higher position in German than in Norwegian.
- He should concentrate on producing a correct /yː/ in German. It is closer to the /uː:/ in Norwegian, both in speech and singing, especially in singing.
- We also see from figure 7 and 8 that the brighter /aː/ in German and the darker /ɑː/ in Norwegian come somewhat closer in quality.

We have only looked at baritone singing. And we have only examined long vowels. We have focused first of all on F1 and F2. The vowel modification process is a lot more complex, and there is a need to continue research and seek for models to comprise all of this complexity in one simple chart or model. Titze argues that a computerized version is probably the answer, tailored for each individual singer. His prime concern is about vowel modification for musical reasons. I, as a phonetician, am primarily interested in explaining the modification effects on language. Since the phonetic vowel space (vowel chart) is an institutionalized and very good model in phonetics to show and explain vowel locations and qualities, I dream of a way of sticking to this model also for sung vowels. The results of my dissertation show that it might be possible although the model needs to be elaborated further.

Figure 9 shows a simplified model of the vowel spaces, the outer bigger one for speech and the smaller inner one for singing. The arrow pointing downwards indicates that vowels might be more open the higher the pitch is, the arrow pointing to the right indicates that vowels often move in that direction, sounding darker and more rounded. The arrows pointing in the opposite directions with the cross, indicate that we normally do not move vowels in these direction. During 35 years of teaching students the phonetics of singing and listening to innumerable native professional singers, it is my experience that singers do not move vowels in these two directions, and if they do, the vowels sound odd. An intended /ьː/ sounding like /iː/ is not likely to happen. A Norwegian /eː/ sounding like a German /e:/ is likewise not acceptable.

The direction of the vowel modification has to be correct first (downwards and to the right); then the fine details of phonemic and phonetic vowel qualities along the correct direction need to be focused on.
Figure 1: Vowel chart as presented by the IPA (International Phonetic Association https://www.internationalphoneticassociation.org/content/full-ipa-chart).

Figure 2: The formant frequencies of F1 and F2 as produced by a male Norwegian singer in speech (Wencke Ophaug, Sangfonetikk, (Bergen: Fagbokforlaget, 2010), 142).
**Figure 3:** The source signal (left) and the resonance of this signal after it has passed through the vocal tract with a specific vowel articulation (right) in a male voice (upper) with a fundamental frequency of 100 Hz, and a female voice (lower) with a fundamental frequency of 200 Hz. (Wencke Ophaug, Sangfonetikk, [Bergen: Fagbokforlaget, 2010], 134-139).

**Figure 4:** The source signal (left) and the resonance of this signal (right) after it has passed through the vocal tract in a soprano voice singing on the high C with a fundamental frequency of about 1000 Hz and with the same vowel articulation as in figure 3. (Wencke Ophaug, Sangfonetikk, [Bergen: Fagbokforlaget, 2010], 160).
Figure 5: The curves show the mean sound pressure level of the vowel /i:/ (left) with a small mouth opening (and spread lips) and the vowel /a:/ (right) with an open mouth articulation, both vowels spoken by a soprano. The curve peaks indicate the typical formant placements of these vowels in a female voice. In both figures the fundamental pitch and the next two overtones in the same soprano’s voice on a “high C” have been inserted to show the “mismatch” between the partials of a high-pitched voice and the articulation properties of the spoken vowels. However, whereas the first vowel (/i:/) is not consistent with a loud voice (all partials being low in intensity), the articulation of the vowel /a:/ will enhance the fundamental frequency distinctively and thereby increase the carrying power of the sound. This is why a soprano will exchange the vowel /i:/ with the vowel /a:/ on high-pitched notes. (After Wencke Ophaug, “The Challenge of Identifying Vowel Phonemes in Singing”. Text and Tune. On the Association of Music and Lyrics in Sung Verse. (Teresa Proto, Paolo Canettieri & Gianluca Valenti, eds) [Peter Lang AG, International Academic Publishers, Bern, 2015], 308)

Figure 6: Mean sound pressure level of the orchestra (solid line) has its highest level around 300-500 Hz. The special singer’s formant has a very high sound pressure level between 2000 and 4000 Hz, a frequency range in which there is little or no competition with the orchestra SPL-level. This gives the voice a distinctive rise in carrying power (Johan Sundberg, 2014, in personal communication).
Figure 7: Vowel migration in Norwegian from speech to singing in a baritone voice for some of the vowel phonemes. Circles with vowel symbols attached represent the spoken counterparts, the ones without represent the sung counterparts, the lines connect them. (Free after Wencke Ophaug, Vowel Migration and Equalisation in Classical Singing (PhD thesis [University of Oslo, 1999], 93)
**Figure 8:** Vowel modification from speech (filled circles) to singing (empty circles) in German (left) and Norwegian (right).

**Figure 9:** The outer bigger phonetic vowel space of spoken vowels, the inner smaller space of sung vowels and the direction of the vowel modification process in singing. Vowels can move downwards and to the right (A,B), not in the opposite direction (C,D). (Free after Wencke Ophaug, *Sangfonetikk*, [Bergen: Fagbokforlaget, 2010], 171)
2 Bryn Tefel in a personal letter to the author, June 16th, 1997
6 Ingo Titze, 2007, ibid
8 Sten Ternström, Körakustik (Stockholm: Gehmans Musikförlag, 1987) 33
10 Kolbjørn Slethei, Grunnbok i fonetikk for språkstudenter (Oslo: Cappelen Akademisk Forlag, 1996), 95
12 Ingo Titze, 2009, ibid.