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SECONDS UNDER MAGNIFYING GLASS – FOCUS ON PURE INTONATION[1]

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SUMMARY. Several books, studies and videos are available on the Internet on the importance and role of singing in schools and choral singing, and on effective ways of learning songs and choral works. As a result of technological progress, MIDI recordings and digital choral parts are available to choirs and choir leaders to facilitate the rehearsal and learning process. However, what on the one hand seems modern and innovative (digital pianos, audio and video recordings, easy and fast communication, streaming, virtual choirs) can have a negative impact on the other. At international conferences and symposiums, it is common to see choirmasters making hand gestures to sound one or more parts, as a kind of attraction to show off solfa singing. It is not always clear, however, what the intelligent use of solmization can do beyond the two-(three-)part singing or vocal warm-up. The following chapters will point out why reading music with a relative system of solfa is beneficial, and why learning to sing a part or a choral work with the help of piano is less supported.

Keywords: cent system, overtones, whole tones, relative solfa – absolute solfa, hand-signs, pure intonation.

The role of the piano in the learning process

The piano or the digital or virtual keyboard instruments are basically tempered.[3] This means a sort of equal temperament, where the 12

[1] A shorter form was published in the July issue of the International Choral Magazine under the title "*From the three different major seconds to the hand-signs – focus on pure intonation"*. Web. ‹https://ifcm.net/uploads/icb/2023-7/eicb_2023-3.pdf›

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[3] Andreas Werkmeister, a 17th-century organist, composer and theorist, who developed the technique of temperament, divided the pure octave into 12 equally spaced parts.

semitones of the octave are exactly at the same distance from each other. This method of tuning began to spread in practice from the end of the 19th century, when measuring frequencies accurately became possible and thus the study of sound systems outside Europe also. Alexander John Ellis, a 19th-century English mathematician and linguist, developed a new system and unit of measurement for comparing the different temperaments and the pitches they could produce. Using the cent system, he transformed the 2:1 ratio of the octave into a linear scale of 1200 degrees, where intervals can be described by arithmetical differences. The semitone as the smallest pitch interval was defined as $\sqrt[12]{2}$ = 100 cents (the cent is the hundredth of a tempered semitone), while whole tones correspond to 200 cents. In fully equal tuning, all keys are of equal value.[4]

Figure 1

Altered notes		C# D♭		D# E♭			F# G♭		G# A♭		A# B♭		
Natural notes	C_4		D_4		E_4	F_4		G_4		A_4		B_4	C_5
Hz	261,63	277,18	293,66	311,13	329,62	349,23	369,99	392,00	415,30	**440,00**	466,16	493,88	523,25
Cent	0	100	200	300	400	500	600	700	800	900	1000	1100	1200

The Cent System

Related to the question of how to achieve pure singing and to the use of instruments it needs to be observed that *"it is well known that any kind of temperament (which is the basis of piano tuning, for example) is alien to the pure intonation of the choir, and that the piano [...] can never become the basis of a homogeneous sound that blends with the singing voice. Nevertheless, the possibility of using the instrument in the training of pure intonation is a question worth considering, because the singing voice, especially at the beginning, is prone to great fluctuations (much greater than the danger inherent in temperament). Experience has shown that the fixity of the individual notes of an instrument (i.e., not its tuning or its temperament) can be used in the initial stages of eliminating fluctuation by a well thought-out, systematic procedure."*[5] So one can use a piano to play a starting and a control note, as

[4] Ferencziné Ács, Ildikó. "Intonáció – szolmizáció" ("Intonation – solmization"). In: Ferencziné Ács, Ildikó, Pintér-Keresztes, Ildikó. *Pótvonalak – Adalékok az ének-zene tanításához (Leger lines – Additions to the teaching of school music)*. Nyíregyháza: Nyíregyházi Főiskola, 2015. pp. 37-47.

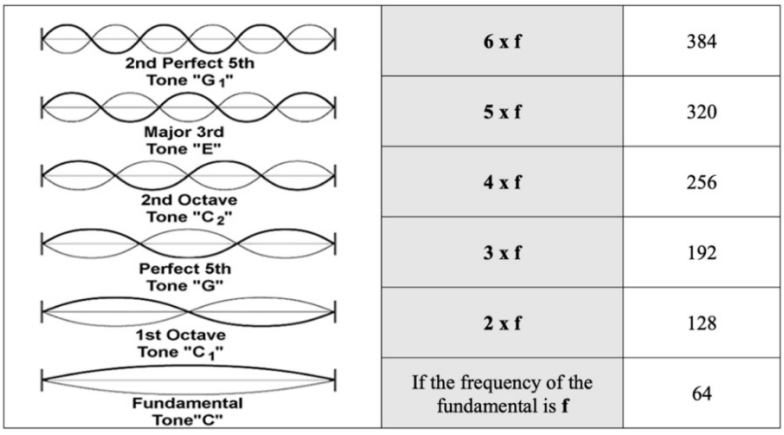
[5] Kardos, Pál. *Kórusnevelés, kórushangzás (Choral education, choral sound)*. Budapest: Zeneműkiadó, 1969, p. 29.

a kind of reference point, i.e., only playing notes that are the same (perhaps in the same octave). "*The part sung by the choir should never be struck on the piano. [...] The instrument is only for the purpose of constantly relating the sound to its starting point"*.[6] The human singing voice is interpreted only in an acoustic context.

Properties of the acoustic overtone series

The human voice, the singing voice as a sound source, can be interpreted as an acoustic signal. When, for example, a string or a vocal cord vibrates, not only the fundamental is heard, but also its frequencies multiplied by whole numbers, its harmonic overtones. The octave has twice the frequency of the fundamental, i.e., the frequency ratio is 2:1. The frequency of the twelfth (octave + fifth) is three times the fundamental, i.e., the ratio is 3:1, etc. The frequency relationships are represented by the successive notes of the overtone series:

Figure 2



Overtones[7]

The ancient Pythagoras established his theoretical scale by measuring strings and then using interval ratios. Based on the Pythagorean tuning, the sequence of notes placed at a perfect fifth distance from each other can be written as follows:[8]

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6 Ibid. 30.
7 Source: ‹https://www.soundsnap.com/blog/glossary/overtone/› Web. 12. Jan. 2023.
8 Fiala, Péter. "A hangszerek fizikája" ("*Physics of musical instruments*"). Jegyzet. Budapest: BME, 2015.

F	c	g	d’	a’	e”	h”	etc.
$\frac{2}{3}$	1	$\frac{3}{2}$	$\left(\frac{3}{2}\right)^2$	$\left(\frac{3}{2}\right)^3$	$\left(\frac{3}{2}\right)^4$	$\left(\frac{3}{2}\right)^5$	

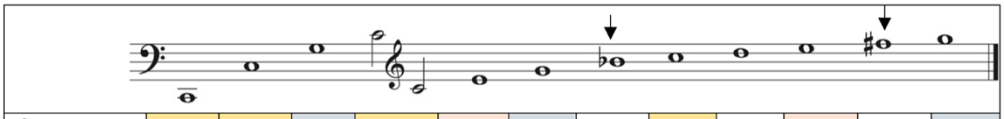
However, despite the apparent identity, the result of the 12 fifths built on top of each other does not correspond to the continuously doubled value of the 7 perfect octaves, starting from the same point and built on each other.

$$\left(\frac{3}{2}\right)^{12} : \left(\frac{2}{1}\right)^{7}$$

The difference between the two values is 1.0136432, or 23.46 cents, which is about a quarter of a half step. The difference is called a Pythagorean comma. Equal temperament eliminates this phenomenon by narrowing each fifth by 1/12 x 23.46 = 1.955 cents.

The following figure shows a series of overtones projected onto the great C/C_2 (overtones 7 and 11 are deeper than the notes used in the diatonic framework), with the frequency values and ratios associated with the notes below. Colours are used to denote octaves built upon each other.

Figure 3



Overtone serial number	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Frequency relations	1x	2x	3x	4x	5x	6x	7x	8x	9x	10x	11x	12x
Frequency	64	128	192	256	320	384	448	512	576	640	704	768
Frequency ratios		$\frac{2}{1}$	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{7}{6}$	$\frac{8}{7}$	$\frac{9}{8}$	$\frac{10}{9}$	$\frac{11}{10}$	$\frac{12}{11}$	
Intervals		Perfect octave	Perfect fifth	Perfect fourth	Major third	Minor third			Major second Large whole step	Major second Small whole step			

Frequencies and ratios

In the score of the overtone series, major seconds can be seen between overtones 8 and 10. Playing these on the piano means two whole tones of the same size. However, it is clear from the proportions below the intervals that the first interval, 9/8, is wider than the second one, which is 10/9. To distinguish

between the two types of major second, we use the terms 9/8 “large whole step” and 10/9 “small whole step.” The frequency ratio of the two whole notes is 81/80, corresponding to ≈ 22 cents. The difference is called a syntonic[9] (or Didymus) comma.[10]

Comparing the three types of whole tones (major second), the differences in size become apparent. It has been found that the equally tempered keyboard instrument is insensitive to the acoustic environment, i.e., it is not able to nuance the difference between large and small whole steps.

Figure 4 a

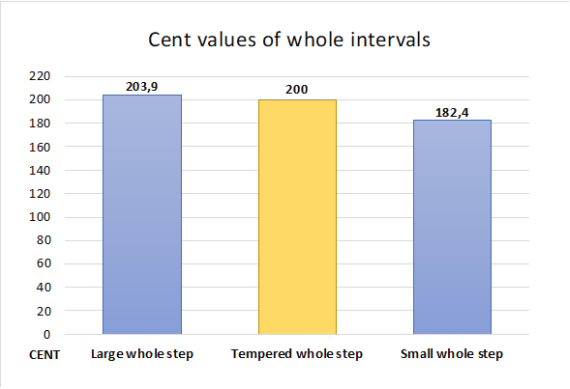


Figure 4 b

Interval	Large whole step	Small whole step	*difference*	Tempered whole step
Ratio	$\frac{9}{8}$	$\frac{10}{9}$	$\frac{81}{80}$	$\sqrt[6]{2}$
Cent	203,9	182,4	21,5	200

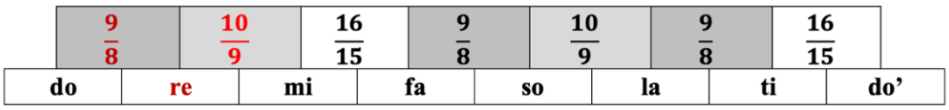
The three kinds of major seconds

The difference between large and small whole steps arising from the difference in acoustic frames is also clearly visible. In the major key, the seconds follow each other in the following order:

[9] This comma is also described by the difference between the Pythagorean major third and the justly tuned major third, i.e., the difference between four perfect fifths jumps + two octaves back and the 5/4 ratio on the perfect natural scale, which can also be described by a ratio of 81/80.

[10] Fiala, Péter. “A hangszerek fizikája” (“*Physics of musical instruments*”). Jegyzet. Budapest: BME, 2015.

Figure 5 a



Major key

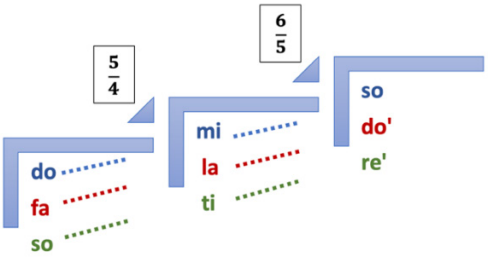
The same in natural minor scale:

Figure 5 b

Natural minor key

On the basis of Figure 3, examining the thirds in the overtone series and the role and behaviour of the notes in the diatonic scale, we can depict the structure of the major triads as follows:

Figure 6

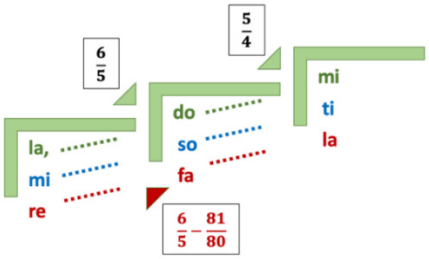


Major triads of the diatonic scale

All the chords have a pure major third and minor third structure. It is no coincidence that these have become the most stable and strongest triads of the major key, the major triads, the carriers of the main functions.

All but one of the minor chords of the diatonic system also sound clear. Only in the minor triad with a **re** root is the semitone forming the minor third paired with the 10/9 small whole step, i.e., the minor third is narrower in this case by a syntonic comma.

Figure 7



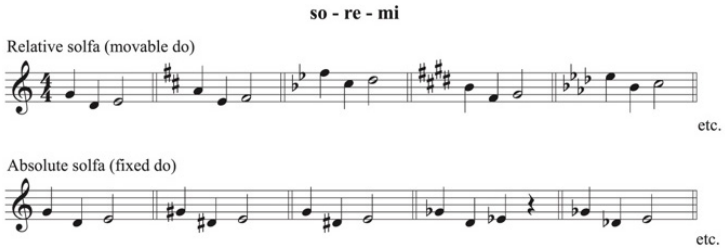
The minor triads of the diatonic scale

It is therefore clear that the **re** note is in a sensitive place, depending on its position and tonal location. The position of a note in a given tonality, its role, the stability of the pure intonation of different intervals and harmonies can be developed through practice. A learning process is effective if "constant" elements occur frequently among the ones to be learned. The more variables there are, the more unstable the memorisation of the turn to be learnt becomes, and the longer the process of deepening takes. Of the two types of solfa systems, absolute and relative ones (also known as "fixed do" and "movable do"), only one can satisfy the above learning process, and that is the relative system.

The role of relative solfa in the development of clear intonation

The learning of tonal music pieces and the clear intonation of melodies and harmonies are ensured by relative solfa. The name of a melody notes, the distance between two notes with the same name, and their role in the tonality are constant. To put it simply, the sound of two intervals with the same solfa name is always the same. For example, in a major key, a **so-re-mi** turn always has a descending perfect fourth and an ascending (small whole step) major second, whatever the key we are in. With absolute solmization, however, the width of the intervals can vary, even with the same name.

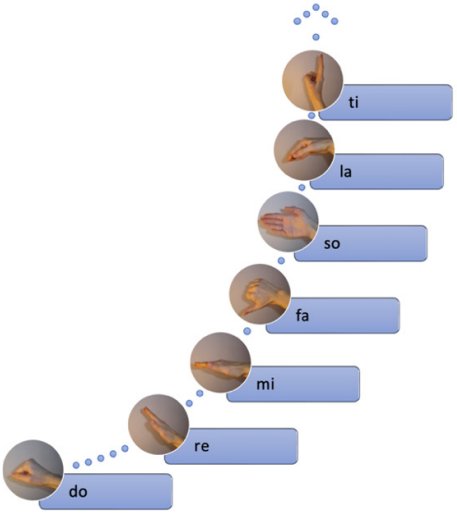
E.g. 1



Relative solfa – absolute solfa

In a tonal musical context, the most suitable method for achieving and practising pure intonation is therefore the use of relative solfa. Automatic use requires a lot of practice, and one of the tools of this is the use of hand signs. Due to their spatial positioning, they offer an excellent opportunity to specify pitches in the right direction and to show the sensitivity of the notes.

Figure 8



Hand-signs

Zoltán Kodály published his booklet *Let Us Sing Correctly*, including exercises in two-part choir exercises in 1941. He writes in the preface: *"Most of our singing teachers and choirmasters believe that singing is pure if it is in tune with the piano. [...] ... the purity of the communal singing is based on acoustically pure intervals and has nothing to do with tempered tuning. [...] What, then, should support the beginner's first steps into the infinite realm of notes? Here is the answer: not a tempered instrument with a contrasting timbre, but a second vocal part. [...] Even pure singing in one part can only be fully learned in two parts. The two parts correct and counterbalance each other. Only those who feel the notes' belonging together when they sing together can hit the right notes one after the other. The* ***do-so*** *jump is more clearly found by those whose ears have the* ***do-so*** *as simultaneously sounded, as a living reality. [...] Each jump must be memorized in itself, in its own particular character and tonal role, and should not be assembled from scale steps*."[11]

[11] Kodály, Zoltán. *Énekeljünk tisztán! (Let Us Sing Correctly*). Budapest: Magyar Kórus Művek, 1941.

Monophonic examples

Pure singing can only be achieved through the interaction of monophony and simultaneous voicing, the foundations of which must be laid in monophony. Conscious attention must be paid to the direction of successive melodic notes: ascension is threatened by a braking force in the lack of sufficient intensity, and a downward step or jump may be deepened even more by some inertia. Effort should be made to assert the intonation of the intervals against the (braking or downward) force of gravity.[12]

When pointing out the difference in width between the large whole step and small whole step, let us make others aware that in both major keys and natural minor keys, large whole steps occur between the following degrees of the scale:

1-**2**.
4-**5**.
6-**7**.

From an intonation point of view, therefore, particular attention should be paid to intoning and sustaining the 2nd, 5th and 7th degrees high. We shall make effort to practice the **large whole step** turns to counteract the direction of gravity.[13]

do-fa-**so**; so,-do-**re**; mi-la-**ti**; la,-re-**mi**

where the **ascending second** in a fifth ambitus should be intoned high, or the **small whole step turns**:

do'-la-**so**; la-**so-**mi; re-**do**-la**,**; so-mi-**re**

in which the **descending seconds** should be intoned high in a fourth ambitus.

Particular attention should be paid to the intonation of the two kinds of **re**. *"If it is close to **do**, **re** is low degree, if it is close to **mi**, **re** is high"*.[14] This can be practiced in a tune example as shown in the following chart:

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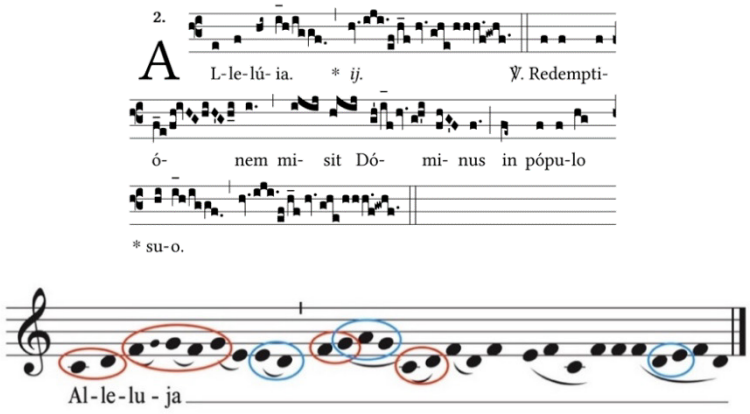
[12] Kardos, Pál. *Egyszólamúság az énekkari nevelésben (Monophony in choral education)*. Szeged: Kardos Pál Alapítvány, 2007.
[13] Ibid.
[14] Kardos, Pálné, Péter Ordasi, Éva Rozgonyi (Ed.). *Kardos Pál (Pál Kardos)*. Budapest: Országos Pedagógiai Könyvtár és Múzeum, 2004, p. 89.

	high re ⬆		***low re***
SO,	***do – re*** – *mi* wide M2	**LA,**	*do* – ***re – mi*** ⬇ wide M2
	*do-**re**-do*		*la,-mi-do*
	*do-**re**-mi-**re**-do*		*la,-mi-do-**re**-do-la,*
	*do-**re**-mi-so-mi-**re**-do*		*la,-mi-do-**re**-mi-do-la,*
			*la,-do-**re**-mi-**re**-do-la,*

Although we have used the term "**low re**" in the minor key, in practice we feel that the **do** and the **mi** are higher, more tense, and the **re** is deeper in comparison.

The two kinds of seconds can be illustrated by different colours in the following sheet music example:

E.g. 2-3



Alleluia[15]

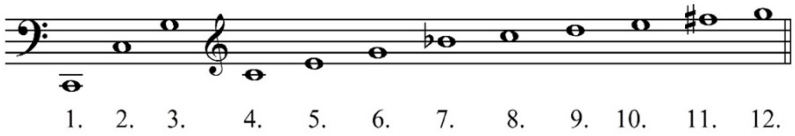
Polyphonic examples

Polyphonic choral exercises can be used according to the skill level of our vocal ensemble. Two-part and polyphonic singing exercises can only be introduced after the starting note has been safely received and the unison sound has been balanced.

[15] Source: ‹https://gregobase.selapa.net/chant.php?id=1341›

In his booklet *Let us Sing Correctly*, Zoltán Kodály proceeds in the order of the acoustic overtone sequence, voicing the octave and fifth intervals, and then in fourths to the sounding of the thirds.

E.g. 4



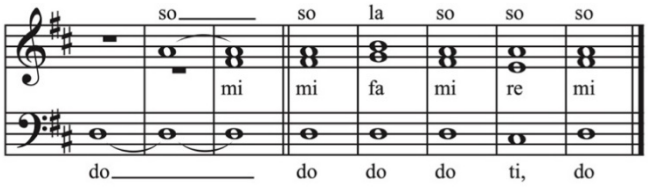
Overtones

However, this sound order cannot be generalised to all choir types and age groups. The perfect fifth and the perfect octave can indeed be defined as the starting point for teaching pure intonation in male choirs, but for female and children's choirs, due to the relative scarcity of overtones resulting from the higher pitch of the fundamental, it is not advisable to start from these intervals. In the case of female and children's choirs, the two kinds of thirds are the most suitable intervals for the beginning, especially the **so-mi** and then the **mi-do** relation.[16] It is therefore no coincidence that the introduction of the tonic major and, almost in parallel, the minor triad is practised first, especially for mixed choirs. It has been shown above that what primarily determines the higher or lower pitch of the **re** note is its relationship to the **so** and **la**, respectively. Therefore, after practising the intervals that make up the triad, it is recommended to intone the perfect fourth below the root (lower **so**). This is followed by conscious practice of the seconds.

When judging the position of the **re**, the tonal context is the determining factor. The **re** in the environment of the **so** behaves differently from when it is surrounded by the **la**. The **so**-related **re** is high, because it is part of the overtone series, and we concentrate mainly on the **re** itself when intoning it.

Examples:

E.g. 5



Major triads

[16] Kardos, Pál. *Kórusnevelés, kórushangzás (Choral Education, choral sound).* Budapest: Zeneműkiadó, 1969.

The example above shows one possible way of combining the three major triads illustrated above in three parts. After the root note is voiced as a solid, firm base, the soft fifth should be played, followed by an even more mellow third. The voice leading is then carried on in second steps, where attention must be paid to the high intonation of the notes **la** and **re**.

So-related high **re**:

An example shown using hand signs *(according to position in the chorus: soprano on the left, alto on the right)*:

E.g. 6

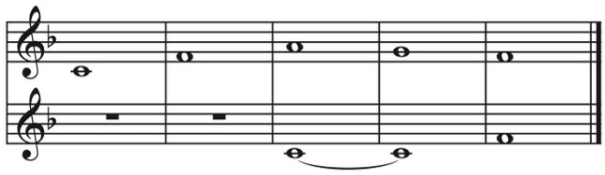
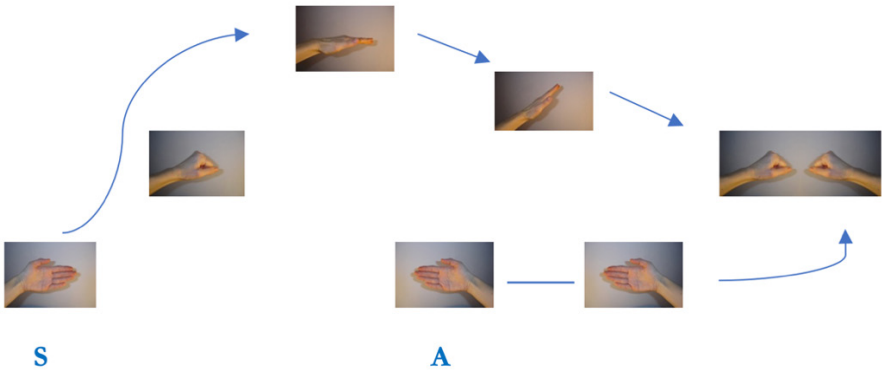


Figure 9

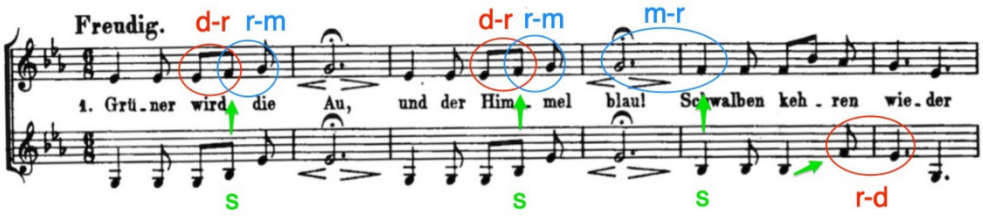


Hand-signs in major tonality

Schubert's *Mailied*[17] clearly shows the behaviour of the **re** in major: above the lower **so**, the **re** is to be intoned high:

[17] Mailied, D.199 (Schubert, Franz). Web. 10. Apr. 2024. https://imslp.org/wiki/Mailied,_D.199_(Schubert,_Franz)

E.g. 7



La-related deep **re**:

An excellent way to practice is when the other part is matched to a sustained note. This offers a chance to relate intervals to a constantly fixed point. The exercise below demonstrates this in minor tonality, using hand signs *(according to the position in the choir: soprano on the left, alto on the right)*:

E.g. 8

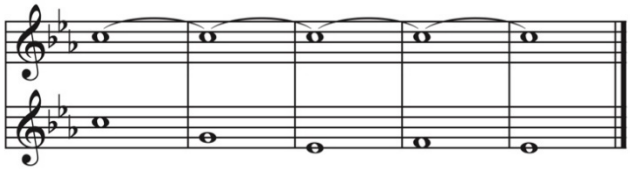
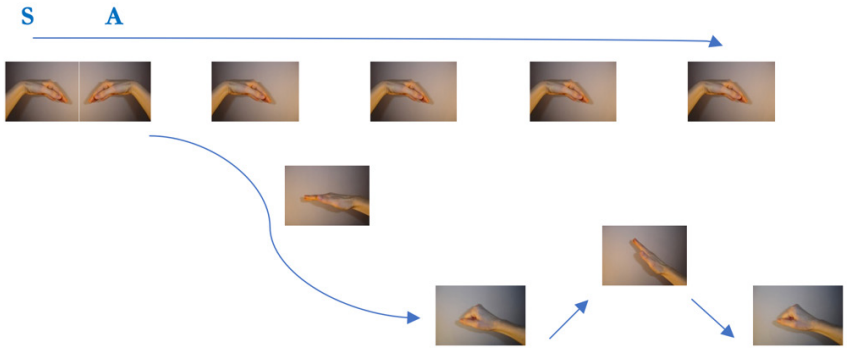


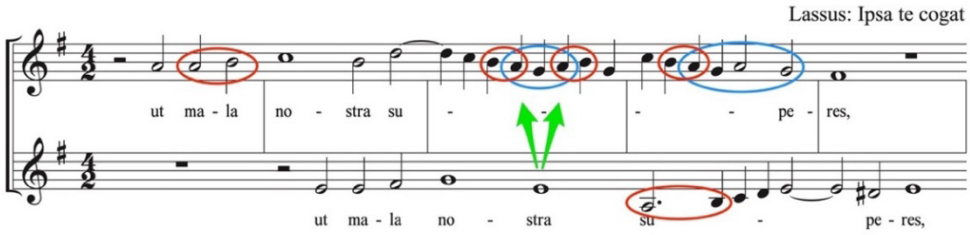
Figure 10



Hand-signs in minor tonality

In the case of a low **re** with a relation to **la**, the most important thing to pay attention to is the pitch of the following tone. E.g., la,-mi-re-**do** or la,-do-re-**mi**. That is, in the first example it is important to achieve a narrower second, in the second one, to achieve a wider second.

E.g. 9



However, the general rule is that it is never possible to have the same kind of whole tone next to each other, because that would preclude the acoustic purity of the major third. It should also be pointed out that the affiliation of the two types of **re** is not always clear. The role of the **re** in the tonality and the proximity of the notes **la** or **so** and the effect of these latter sounds often render it difficult to make a theoretical decision. The frequent changes are influenced by the musical context, the leading of the part and harmonic thinking together.

Conclusions

Hungarian music pedagogy is generally committed to the practice and learning of vocal material and parts without instrumental reinforcement. However, the way in which the learning process takes place is significant. Only in the case of instrumental music does it make sense to think in terms of note names or absolute solfa. Since each key has different note names associated with a given melodic turn, it is more time-consuming to memorise the tone relationships in a vocal framework, and it is also disadvantageous from an intonation point of view as well. For clear singing, it is best if the melodic elements can always be voiced with the same names and syllables, regardless of the key, according to their role in the tonality. The same distance, step or jump can only be given the same name in the relative solfa system. Within the framework of a given tonality, the intonation of the intervals becomes stable and well controllable.[18]

[18] Ferencziné Ács, Ildikó. “Intonáció – szolmizáció” (“Intonation – solmization”). In: Ferencziné Ács, Ildikó, Pintér-Keresztes, Ildikó. *Pótvonalak – Adalékok az ének-zene tanításához (Leger lines – Additions to the teaching of school music)*. Nyíregyháza: Nyíregyházi Főiskola, 2015. pp. 37-47.

Apart from clear intonation:

- Same intervals will recall the same tone names through persistent practice (automation). If the association is strong enough, it becomes possible to write them down – musical writing is created.
- The practice aimed at identifying the notes and tone names that are seen can bring out their sound, and the melody can be heard through inner hearing or be actually sounded, i.e., – musical reading is realised.

REFERENCES

Ferenczíné Ács, Ildikó. “Intonáció – szolmizáció” (“Intonation – solmization”). In: Ferenczíné Ács, Ildikó, Pintér-Keresztes, Ildikó. *Pótvonalak – Adalékok az ének-zene tanításához (Leger lines – Additions to the teaching of school music)*. Nyíregyháza: Nyíregyházi Főiskola, 2015. pp. 37-47. Print.

Fiala, Péter. “A hangszerek fizikája” (“Physics of musical instruments”). Jegyzet. Budapest: BME, 2015. Web. 10. Apr. 2024. ‹https://last.hit.bme.hu/sites/default/files/documents/hangfiz.pdf›

Kardos, Pál. *Kórusnevelés, kórushangzás (Choral Education, choral sound).* Budapest: Zeneműkiadó, 1969. Print.

Kardos, Pál. *Egyszólamúság az énekkari nevelésben (Monophony in choral education)*. Szeged: Kardos Pál Alapítvány, 2007. Print.

Kardos, Pálné, Péter Ordasi, Éva Rozgonyi (Ed.). *Kardos Pál (Pál Kardos)*. Budapest: Országos Pedagógiai Könyvtár és Múzeum, 2004. Print.

Kodály, Zoltán. *Énekeljünk tisztán! (Let Us Sing Correctly*). Budapest: Magyar Kórus Művek, 1941. Print.