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# Common base of western and non-western scales derived from vocal tract resonances

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## Introduction

The human voice is considered predominant in the emergence of music as a whole and vocal capabilities in combination with hearing abilities are regarded to support the emergence of intervals in any cultural setting [1].

Physical properties of the vocal tract give rise to relations that have been linked to intervals on an auditory level [2]. The present work focusses on vocal ergonomics due to vocal tract resonances as possible driving force for the emergence of intervals or scales.

## Methods

The spectra and sound pressure level of an externally stimulated 3D vocal tract model [3] during a pitch glide was recorded and analysed. The experimental data are compared via a semi-empirical simulation procedure first introduced by Fant [4].

## Background, Results and Discussion

At comfortable singing range close to average speaking frequency the vocal tract resonances $f_{Rn}$ are considered to be constant at a given vowel at first approximation. The average speaking frequency is linked to the first and second vocal tract resonances [4]. A vocal tract resonance supporting a harmonic will amplify most effectively at multiples of the fundamental frequency $f_0$. Since vocal tract resonances are much higher than any $f_0$ used during speaking, even the first resonance $f_{R1}$ can support multiple fundamental frequencies, e.g. $f_{o,n(1)}$ at $f_{R1}/n_1$ or $f_{o,j(1)}$ at $f_{R1}/j_1$ with n and j being multiples of different supported fundamental frequencies . The two $f_0$ which are both supported by a given $f_{Rn}$, are related by

$$f_{o,j(1)} = \frac{n}{j} * f_{o,n(1)} \quad \text{or} \quad f_{o2}/f_{o1} = \frac{n}{j} \qquad (1)$$

with $f_{o1}$ and $f_{o2}$ being the supported fundamentals respectively. The ratios of the integral numbers of the harmonics n and j define thus the resulting intervals.

Fig. 1 shows the case where both $f_{R1}$ and $f_{R2}$ support a fundamental frequency of 130 Hz. Besides the support at this frequency $f_{o1}$ (130 Hz), $f_{R1}$ supports the fundamental frequencies at $f_{o2} = 5/4 * f_{o1}$ which is a major 3rd and a mayor 6th ($f_{o2} = 5/3 * f_{o1}$) as well. $f_{R2}$ will support a sharp whole tone (8/7), a perfect 4th (4/3), a minor 6th (8/5) and an octave (2/1).

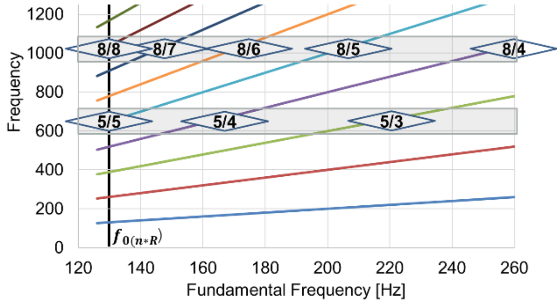


*Figure 1: Schematic view of a pitch glide and the passage of harmonics across the $f_{R1}$ and $f_{R2}$ shown for the vowel [a:] of a male voice: $fo_1$ = 130 Hz, $f_{R1}$ = 520 Hz and $f_{R2}$ = 1170 Hz.*

Fig. 2 gives a general view on supported intervals.

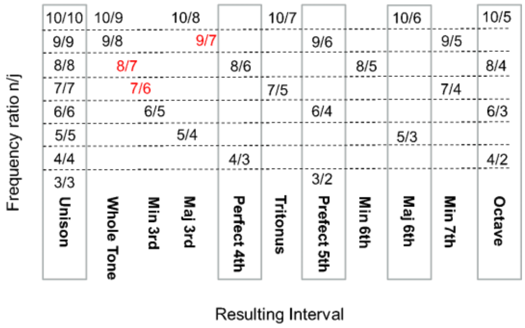


*Figure 2: Formant-supported intervals based on a support of a given vocal tract resonance within the first 10 harmonics.* ***Black:*** *intervals matching the diatonic system. Red: Intervals not found in traditional western music.*

Fig. 2 includes 10 pure intervals used in classical western music including the Tritonus while the minor second and a mayor 7th are missing. The intervals defined by the frequency relation of 9/8 are part of the traditional Indian Shrutis system while a lower minor 3rd and 4th are found e.g. in Arabian 24 scales. Thus, based on the purely physiological approach towards vocal tract ergonomic, different cultures may have chosen selected intervals to be »correct« in the sense that these intervals are equally supported by the human voice.

## References

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