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

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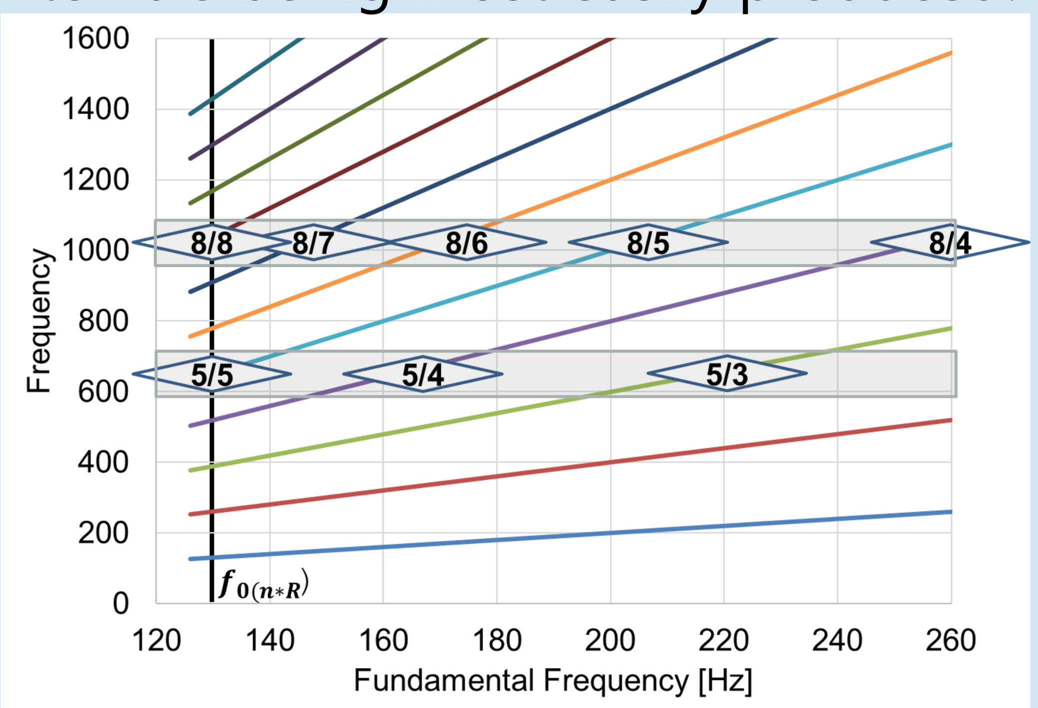
Introduction

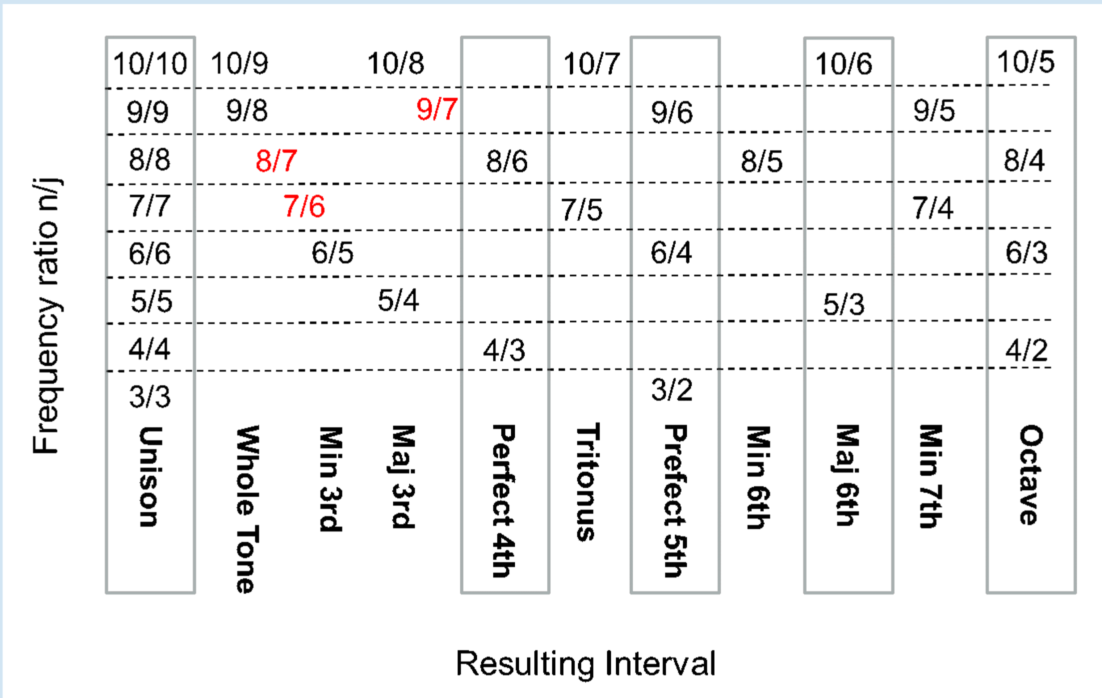
The emerging of music dates back to early times in cultural history and all present human cultures know music based on discrete intervals[1]. For the origin of scales mainly vocal capabilities in combination with hearing abilities may be considered[2]. While the human hearing system is important to recognize relative pitches and similarities, physical properties of the voice determine whether intervals may be easily produced[3]. The present work focusses on vocal ergonomics[4] as possible driving force for the emergence of intervals/scales including western and non-western intervals.

Theory and Simulation

The average speaking frequency is linked to the first and second VT resonances and any supported frequency is found at $f_{o,j(1)} = \frac{n}{j} f_{o,n(1)}$ or $f_{o2}/f_{o1} = \frac{n}{j}$ with n and j being multiples of f_o. Constant VT resonances thus define the intervals being most easily produced.



Schematic view of a pitch glide and the passage of harmonics across the ƒR1 and ƒR2 shown for the vowel [a:] of a male voice: ƒo1 = 130 Hz, ƒR1= 520 Hz and ƒR2 = 1170 Hz.

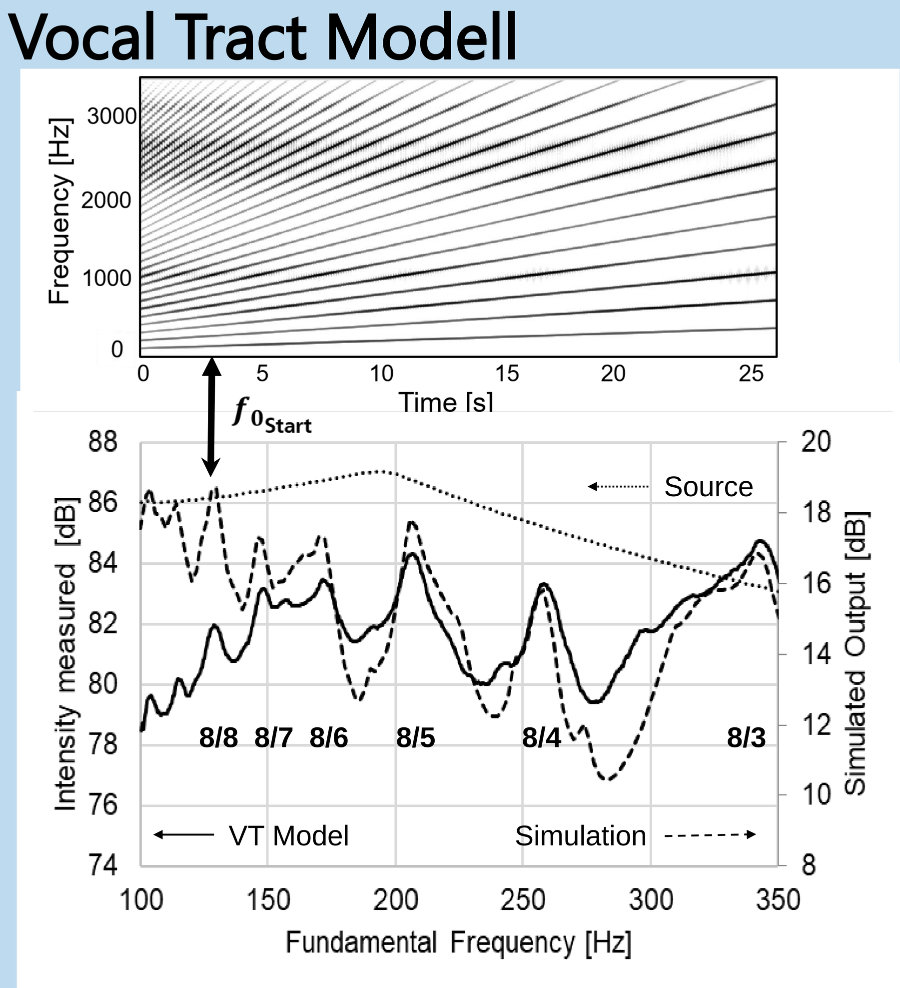


*Formant-supported intervals.. **Black:** intervals matching the diatonic system. **Red:** Intervals not found in the diatonic system*

Simulation is based on a semi empiric approach first introduced by Fant[5] based on a spectrum of the primary source and positions and bandwidths of the first four formants.

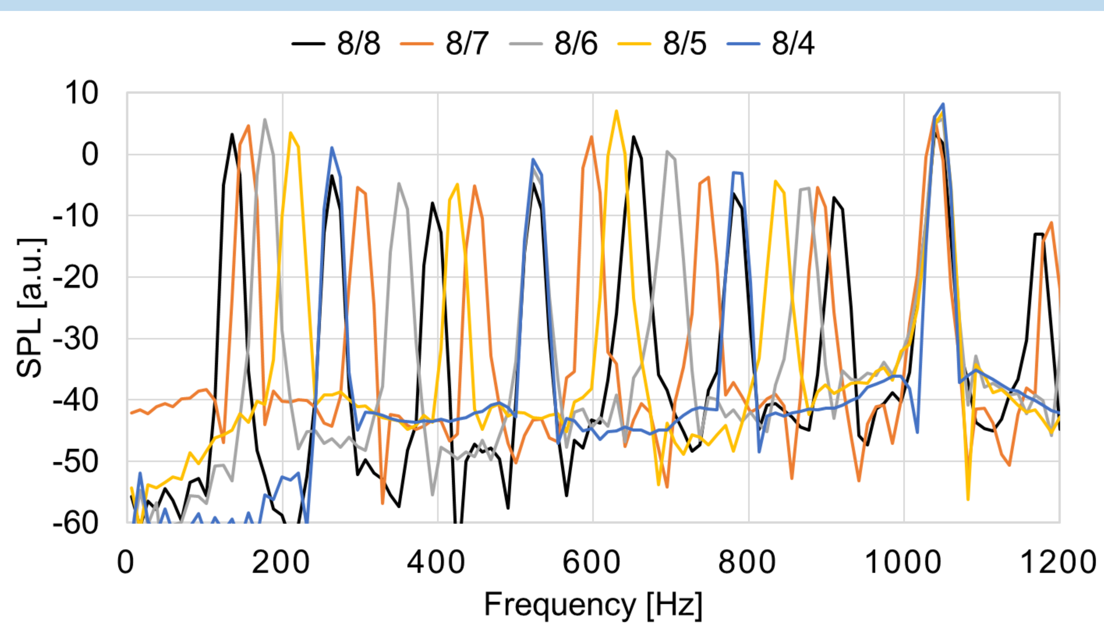
Results

Vocal Tract Modell



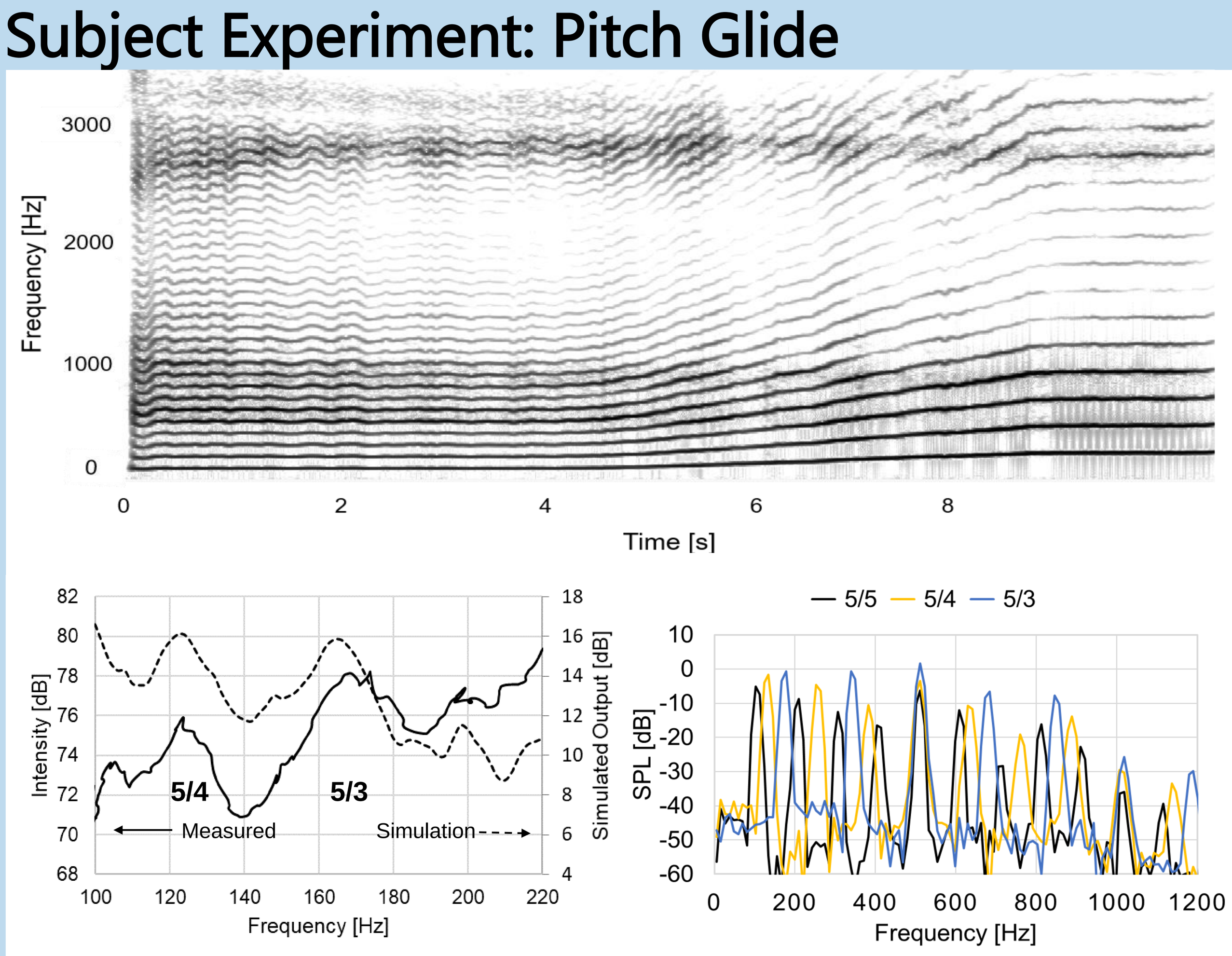
*3D VT Model pitch glide from 100 Hz – 350 Hz. **Upper Part:** spectrogram. **Lower Part:** measured intensity and simulated amplification with formant frequencies of 645 Hz, 1032 Hz, 2470 Hz and 2730 Hz.*

Pitch glides show intensity peaks related formant-supported intervals.



***Spectra of VT-Model** at intervals supported by the 2nd formant:*
Black: $f = 8/8\, f_{start}$ *(129 Hz), :*
Red: $f = 8/7\, f_{start}$ *(large whole tone,147 Hz),*
Grey: $f = 8/6\, f_{start}$ *(4th,172 Hz), :*
Orange: $f = 8/5\, f_{start}$ *(min 6th,222 Hz)*
Blue: $f = 8/4\, f_{start}$ (Octave 258 Hz)

Subject Experiment: Pitch Glide



***Upper part:** spectrogram during a pitch glide form 100 Hz to 220 Hz:*
Lower part, left:** measured intensity and simulated amplification with formant frequencies of 500 Hz, 800 Hz, 2500 Hz and 2700 Hz. **Right:** intervals supported by the second formant: **black: $f = 5/5\, f_{start}$ *(100 Hz),*
orange: $f = 5/4\, f_{start}$ *(maj. 3rd 125 Hz)*
blue: $f = 5/3\, f_{start}$ *(maj. 6th at 167 Hz).*

Discussion and conclusion

Defined intervals will be supported if the singer can rely upon the individual VT resonances, not necessarily on the human ear and a focus on vocal output / vocal ergonomics alone may support pure intervals. Additional supported intervals are found e.g. within the first 3 whole tones as the minor/mayor septimal third or a augmented whole tone. While during the experiments using a 3D VT model no changes of spectral slope or VT geometry are expected, the underlying concept may help to learn how to produce pure intervals in and outside the western musical scale.

Literature

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