Exploring the relationship between voice leading, harmony, and intonation in a capella SATB vocal ensembles.

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Introduction

Experimental Method

Extraction and Analysis of Intonation Data

Results

Conclusions

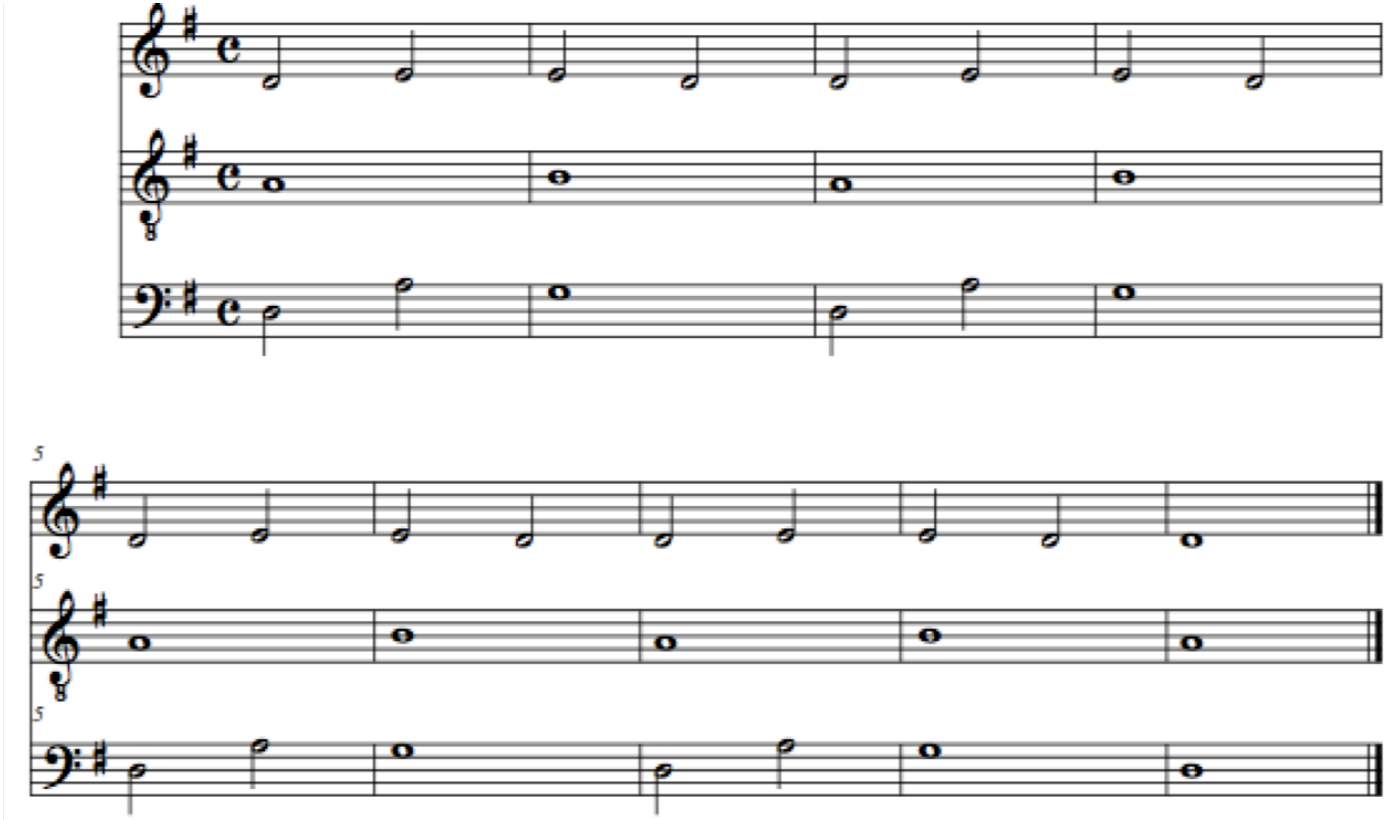
Future Work

Introduction

- Empirical evaluations have shown that singers do not sing in any fixed tuning system (Prame 1997; Jers & Ternström 2005; Howard 2007a, 2007b)
- This paper presents a study of intonation tendencies in SATB ensembles
- This ongoing study explores
  - The degree of consistency across an ensemble's performances of a musical passage
  - Whether the organization of musical materials influences intonation
    - This paper will focus on drift

Experimental Material

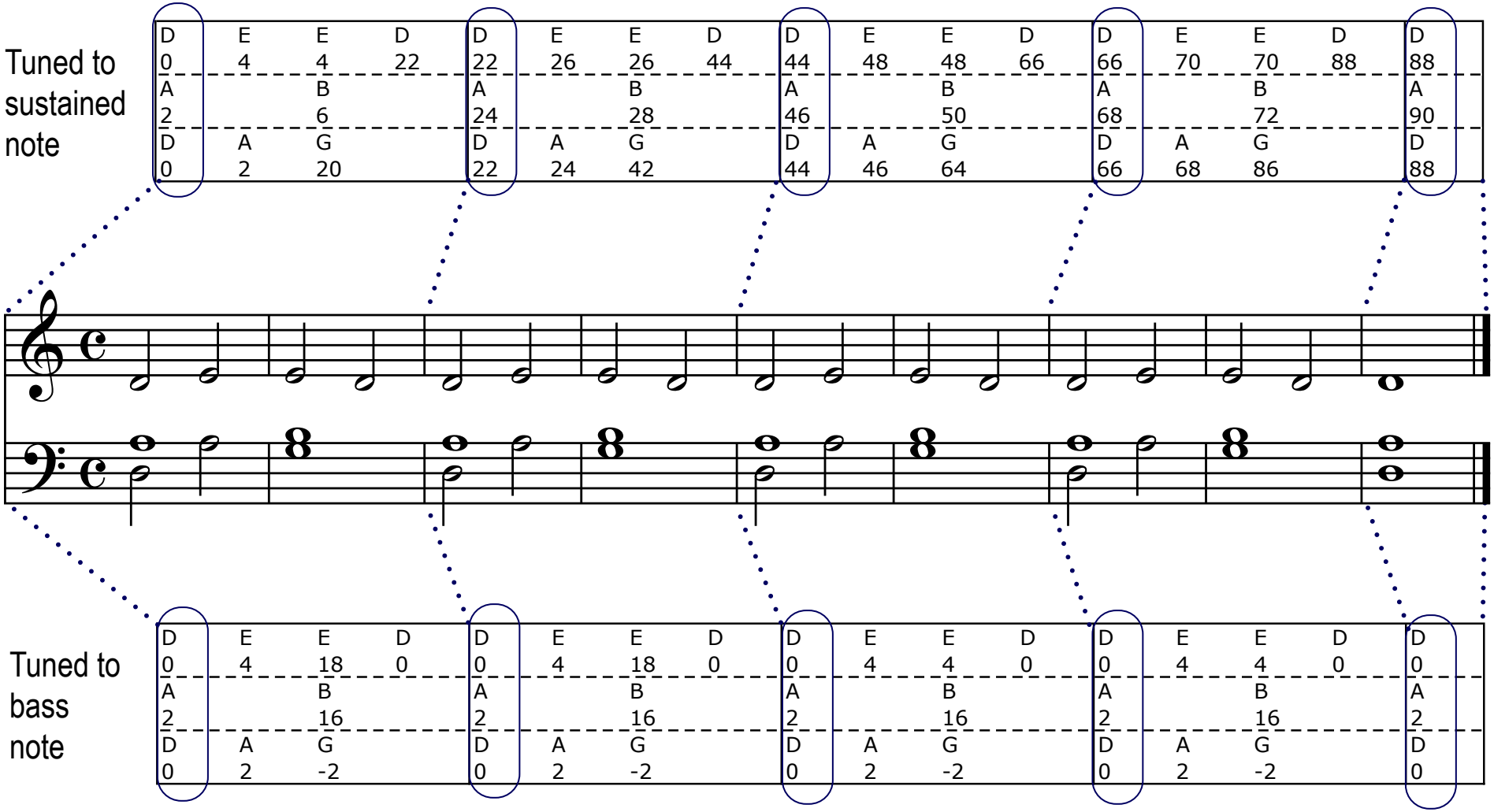
- Chord progression by Giambattista Benedetti (1530–90)



Many thanks to Gabriel Vigliensoni for creating the Vocaloid versions

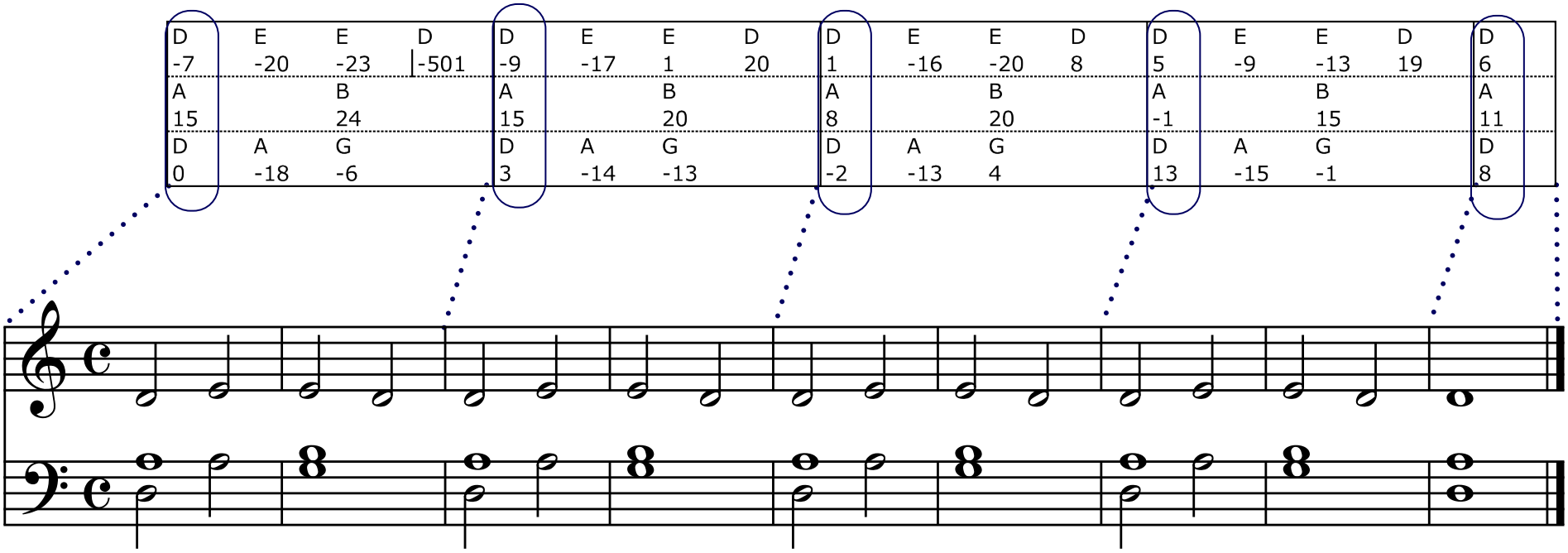
Experimental Material

Theoretical intonation calculations for the chord progression



Experimental Material

Example of actual performance



Experimental Subjects

- Ensemble 1 – Semi-professional singers* (ATB, lab)
- Ensemble 2 – Professional singers** (ATB, lab)
- Ensemble 3 – Professional singers** (SAT, church)
- Ensemble 4 – Professional singers** (ATB, church)

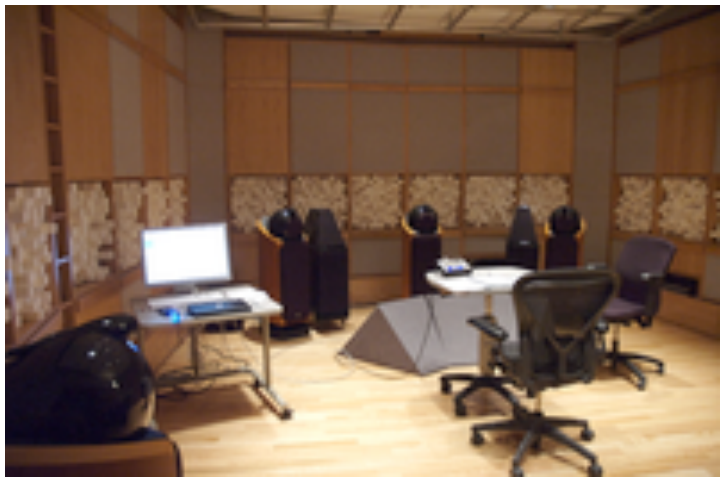
**no conductor* ***conducted by Peter Schubert*

Preliminary Results - Matching

- Semi-professional SATB ensemble
  - Average age: 26 (*SD*=3.6)
  - Average number of years of private voice lessons: 6.5 (*SD*=4.5)
  - Average number of years of regular practice: 6.5 (*SD*=2.5)
  - Average amount of daily practice: 0.75 hours (*SD*=0.84)
- Professional SATB ensemble
  - Average age: 42 (*SD*=9)
  - Average number of years of private voice lessons: 7.75 (*SD*=0.5)
  - Average number of years of regular practice: 24 (*SD*=10)
  - Average amount of daily practice: 1.75 hours (*SD*=1)

Experimental Method

- Recording set-up (Ensembles 1 & 2)
  - Room – 4.85m x 4.50m x 3.30m lab with low noise, reflections, and reverberation time (ITU-standard)
  - Each singer was miked with a cardiod headband mic (DPA 4088-F)
  - The microphones were run through a RME Micstasy 8 channel microphone preamplifier and RME Madi Bridge
  - Recording was done on a Mac Pro

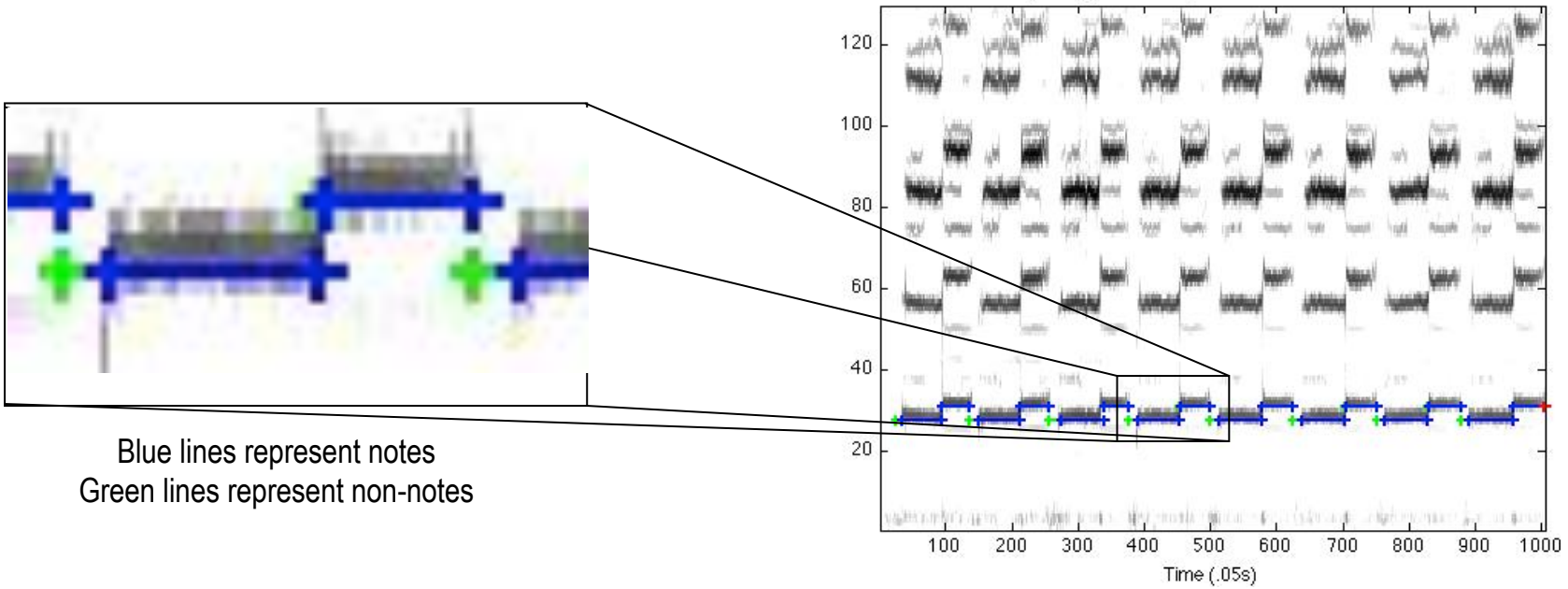


Experimental Method

- Recording set-up (Ensembles 3 & 4)
  - Room – St Mathias Church, Montreal, Canada
  - Each singer was miked with a cardiod headband mic (DPA 4088-F)
  - Recording was done on a Zaxcom Deva 16 (with built in microphone pre-amps)

Extraction of Intonation Data

- Labelling of note onsets and offsets in the recordings was done automatically
  - This research uses a hybrid dynamic time warping(DTW)/hidden Markov model(HMM) alignment algorithm optimized for the singing voice (Devaney, Mandel, & Ellis 2009)

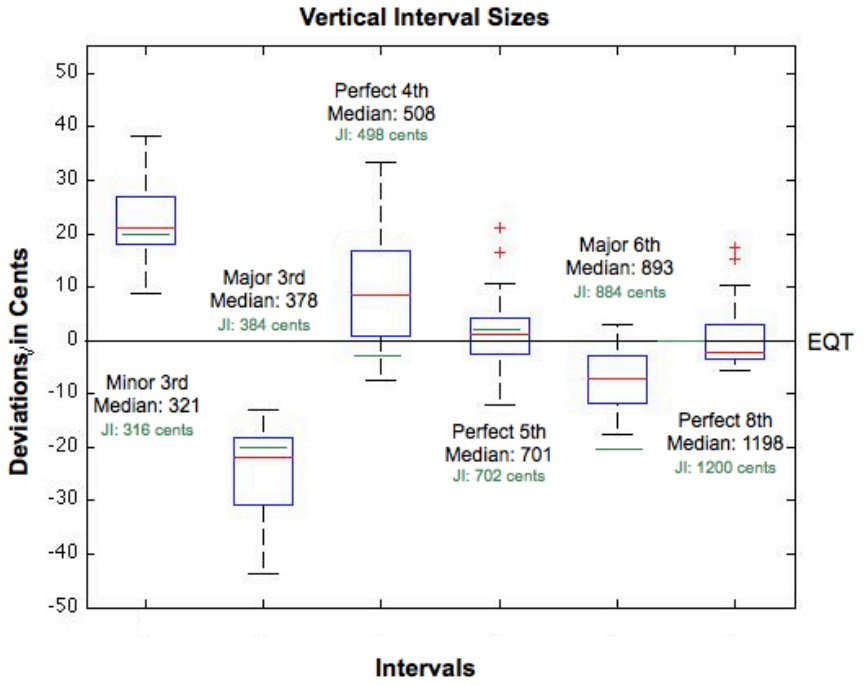


Blue lines represent notes
Green lines represent non-notes

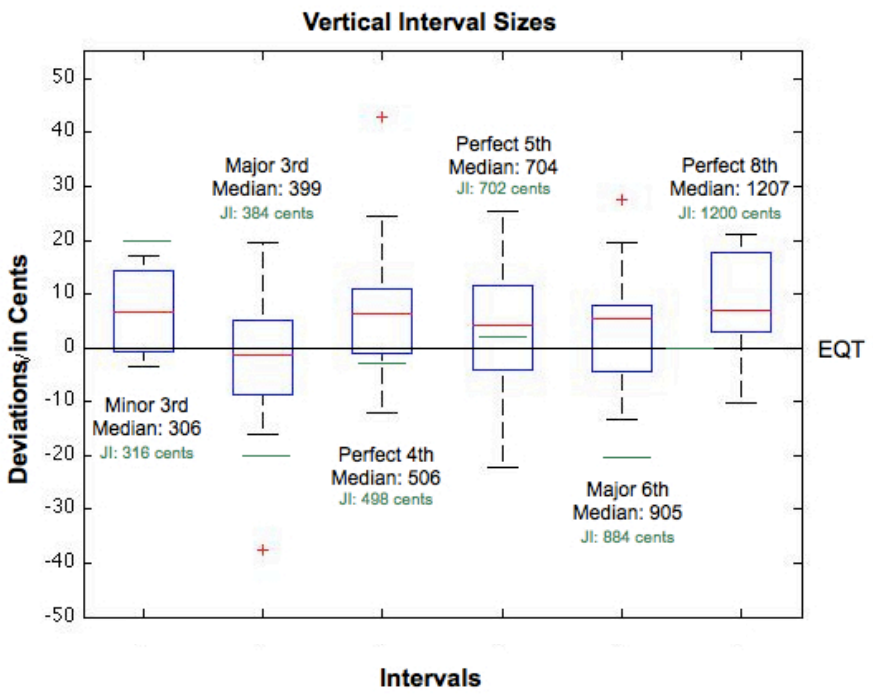
Extraction of Intonation Data

- Fundamental frequency (F_0) estimation for each frame of audio
  - This research uses the YIN algorithm (de Cheveigné & Kawahara 2002)
- Horizontal intervals were calculated with the mean pitch over the duration of each note
- Vertical intervals were calculated by taking the mean of frame-wise calculations of the vertical distance between two voices

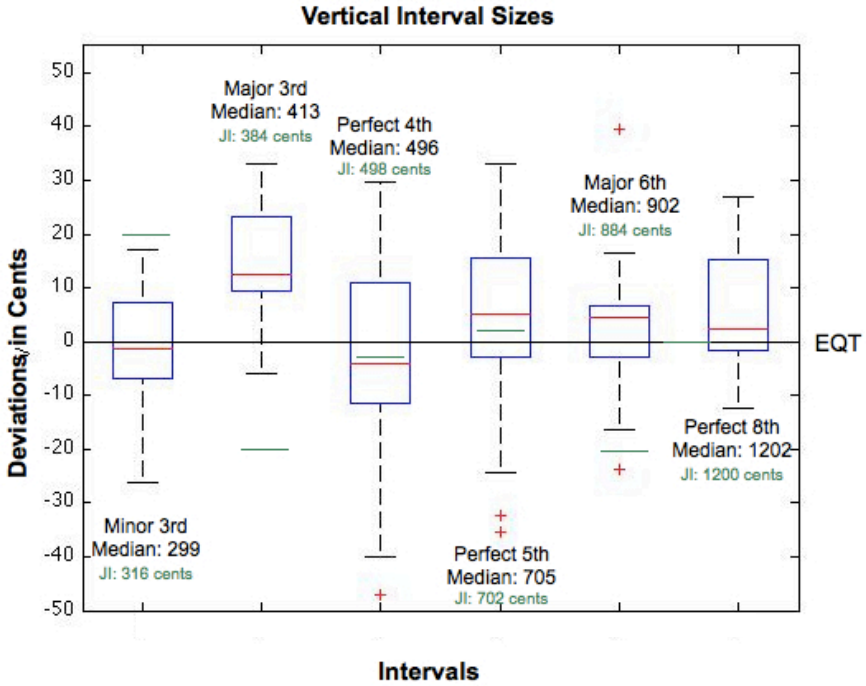
Ensemble 1



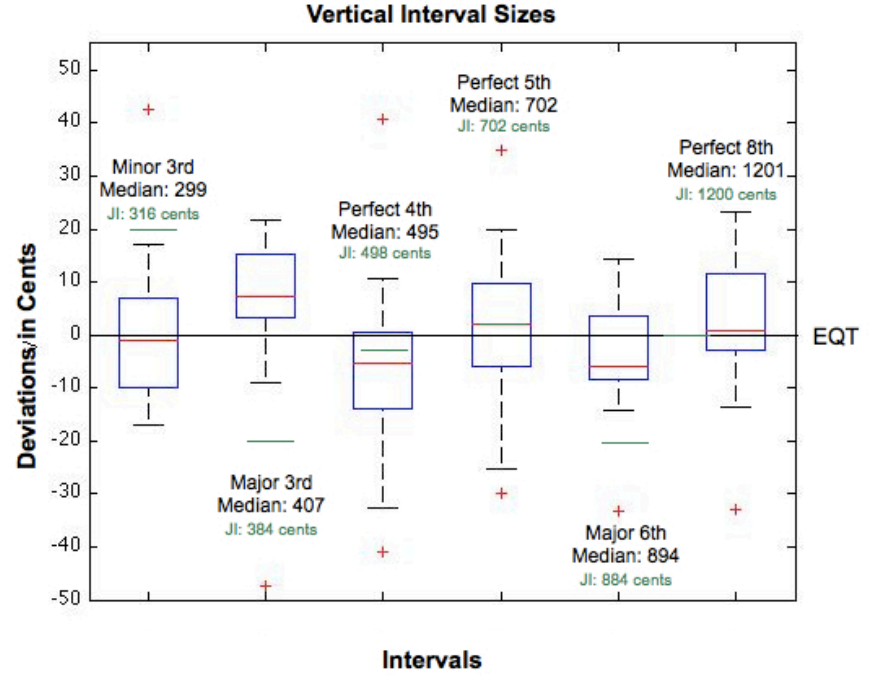
Ensemble 3



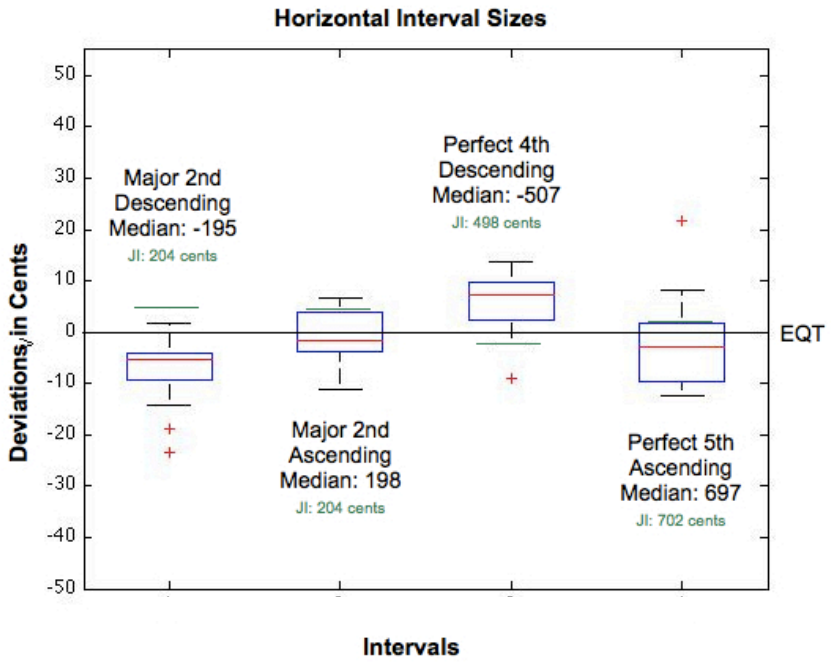
Ensemble 2



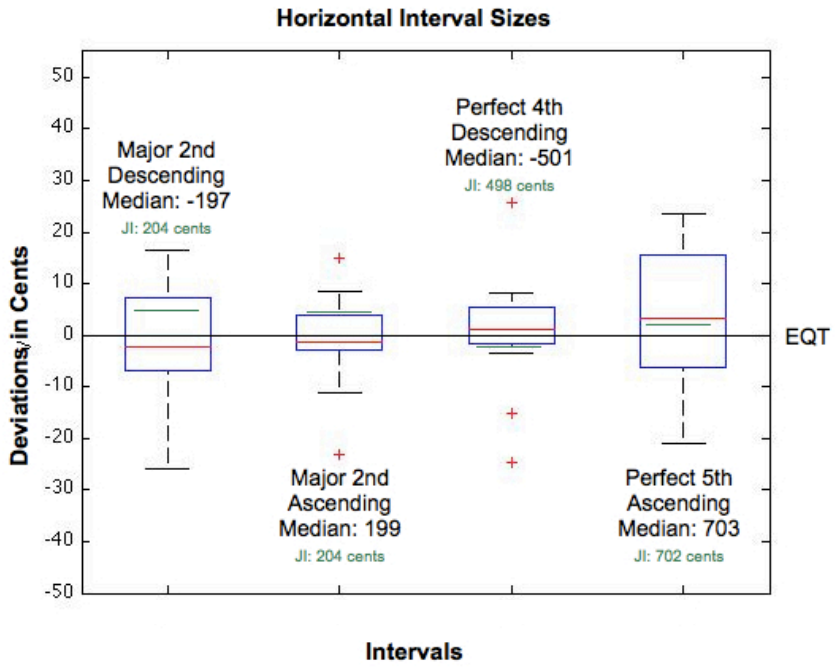
Ensemble 4



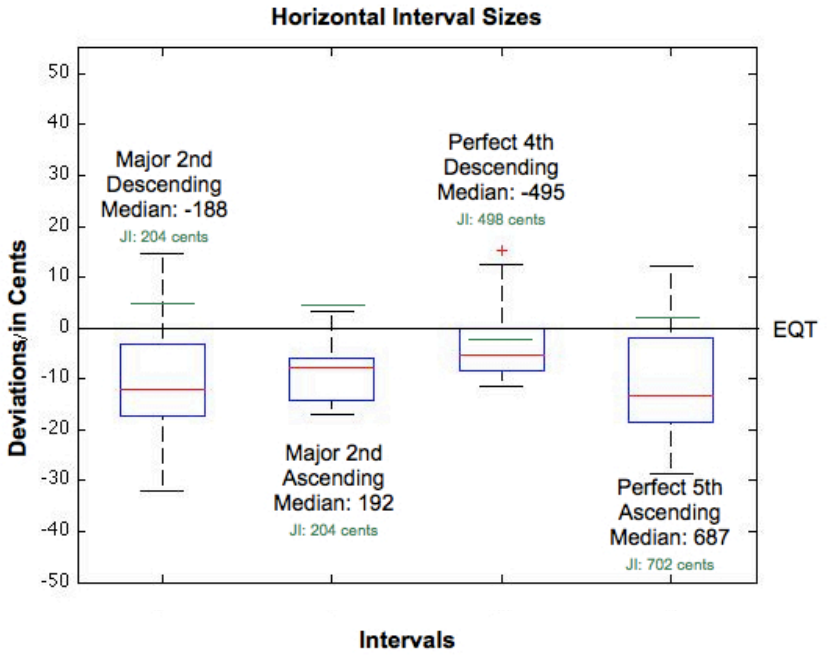
Ensemble 1



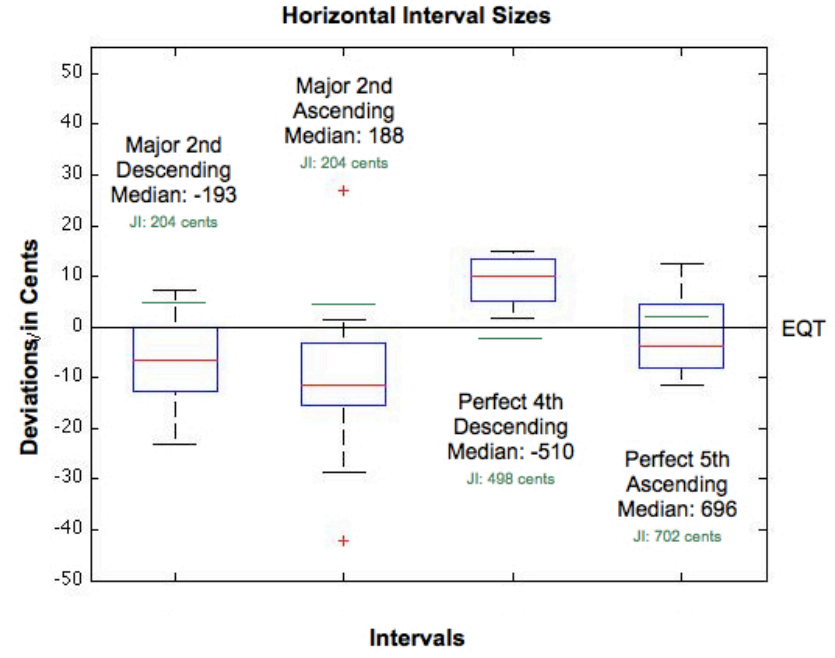
Ensemble 3



Ensemble 2



Ensemble 4



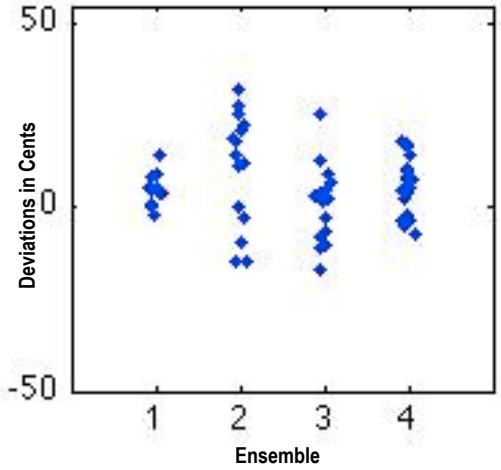
Major Seconds

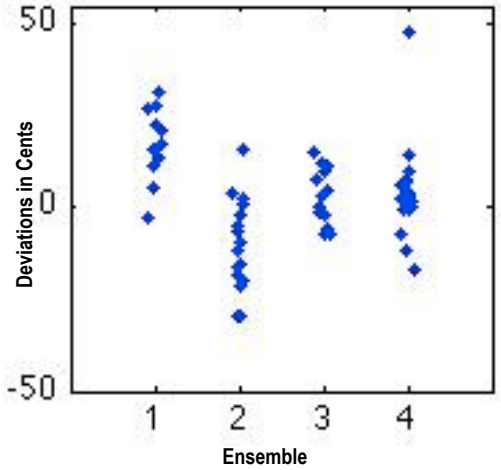
Top voice

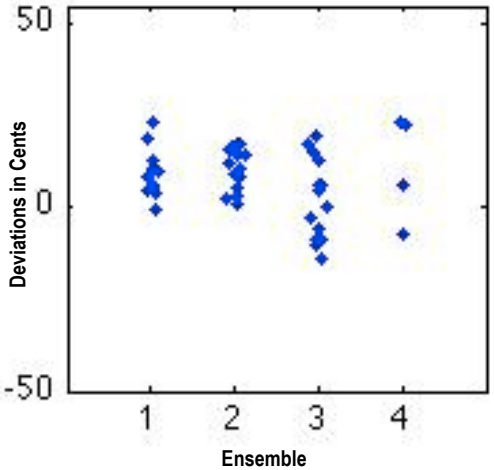
Middle voice

Bottom voice

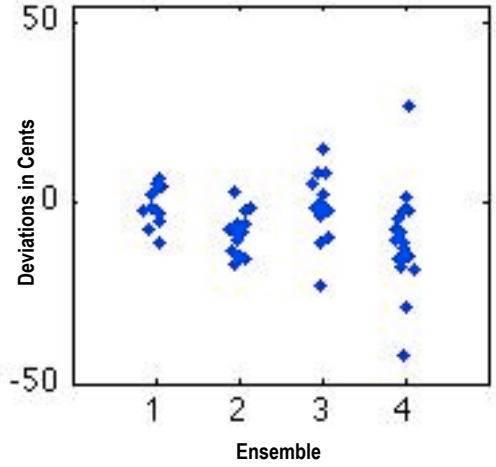
Major Seconds Descending

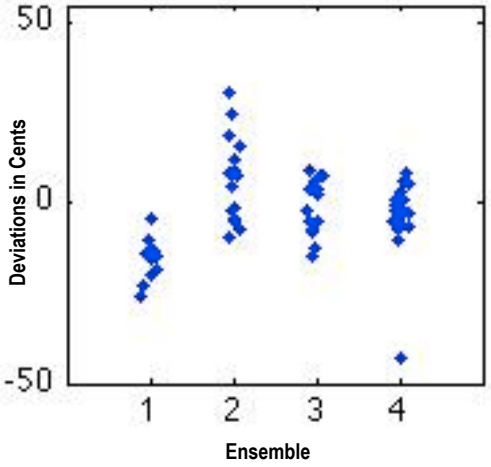


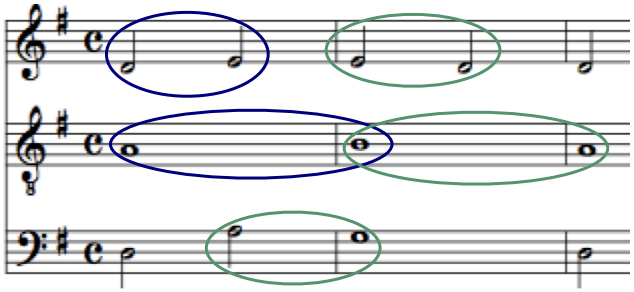




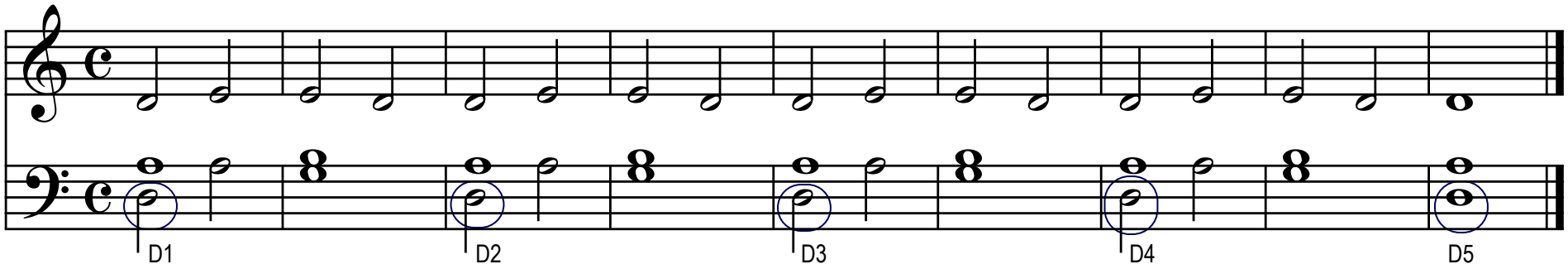
Major Seconds Ascending



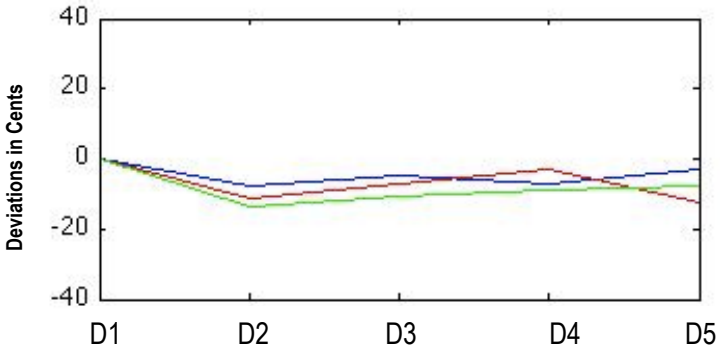




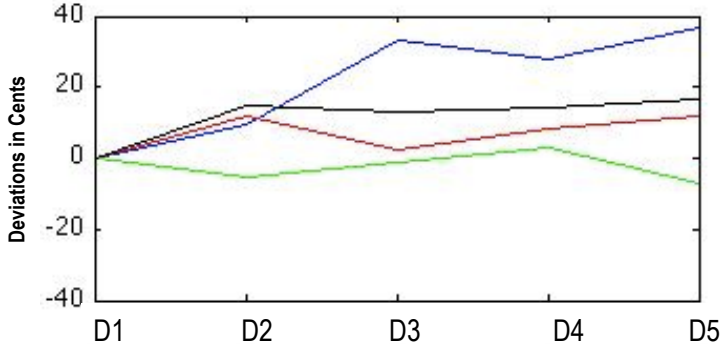
Drift



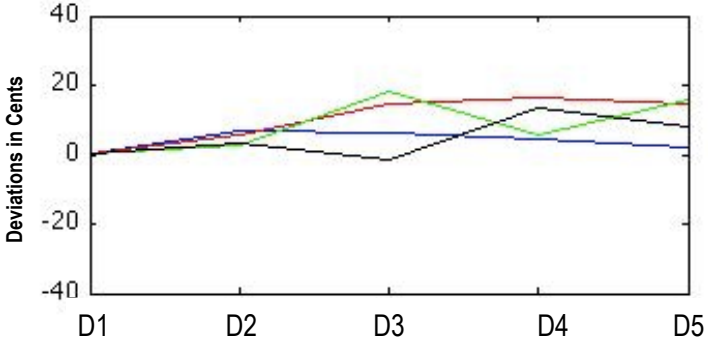
Ensemble 1



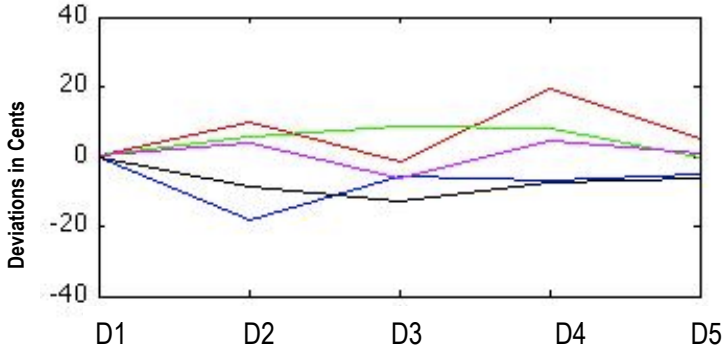
Ensemble 3



Ensemble 2

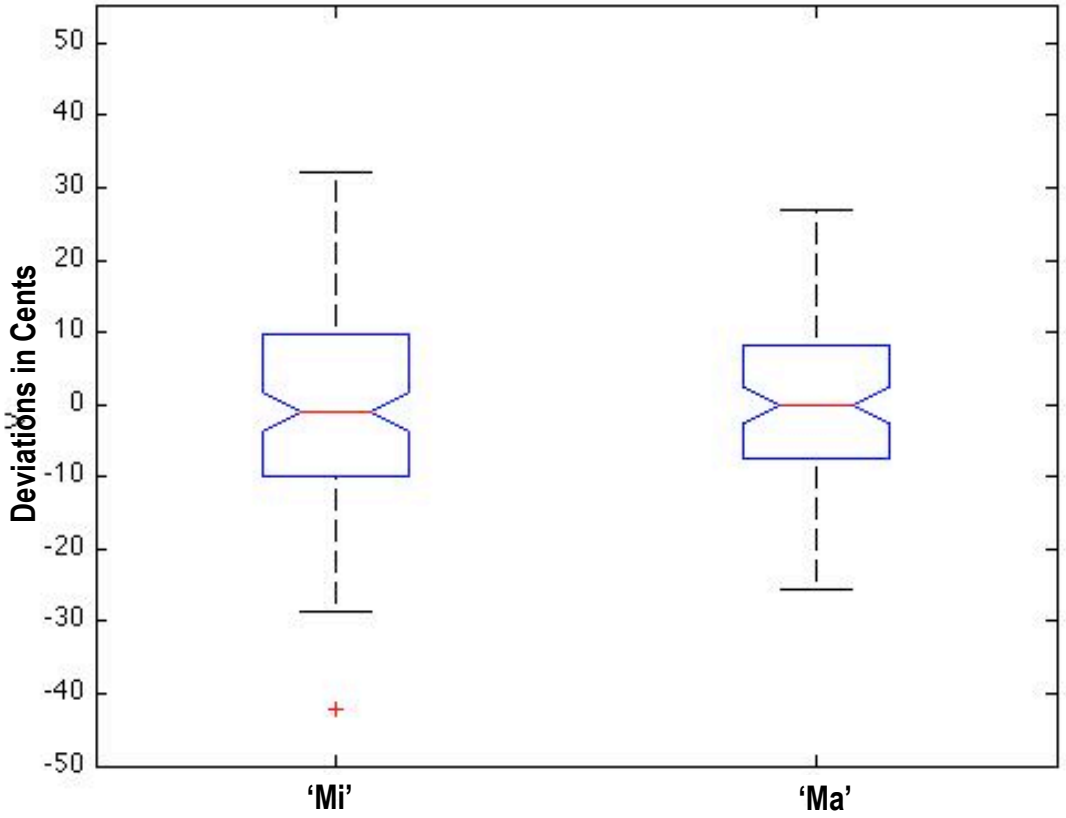


Ensemble 4



Impact of vowel

Ensemble	# takes with 'mi'	# takes with 'ma'
~~1~~	~~3~~	~~0~~
2	2	2
3	2	2
4	3	3



Conclusions

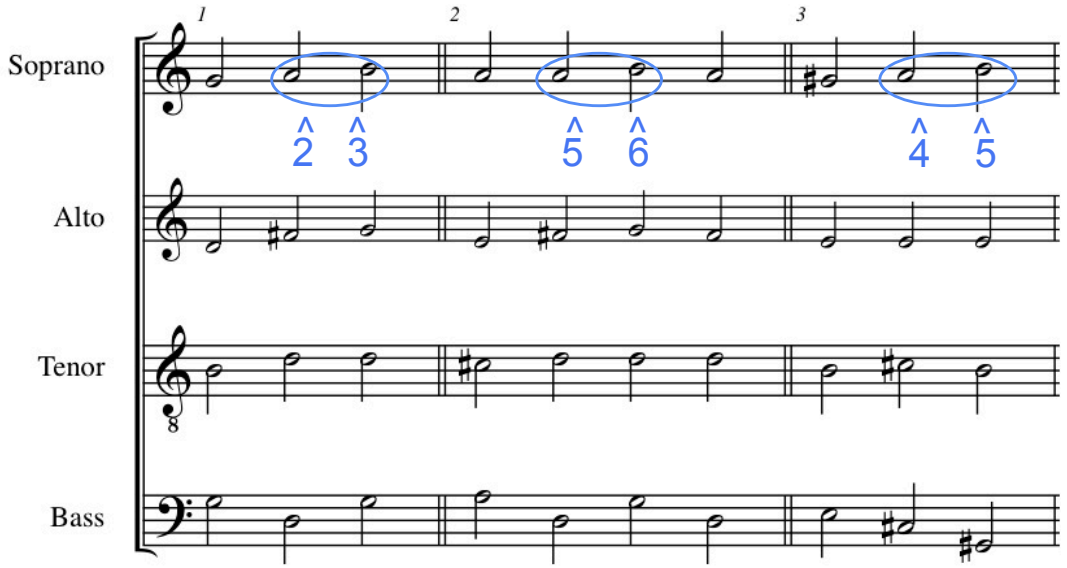
- We observed variation in the sizes of the horizontal and vertical intervals
  - The interval sizes conformed to neither Equal Temperament or Just-Intonation
  - Significant differences were found in the size of the ascending versus descending major seconds
- Variable amounts of drift were observed in the ensembles
  - None of the ensembles conformed to the sharpening predicted by Benedetti
- Vowel did not significantly impact tuning

Future Work

- Open questions
  - Is there a better model for perceived pitch?
    - Or more relevant descriptors?
  - How much variation (in cents) is significant across performances?
  - What is the effect of more than one singer to a part?

Future Work

- More experiments
  - Individual singers matching pitches and singing sequential and simultaneous intervals against recorded stimuli
  - Individual singers with a recorded N-1 ensemble
  - Shorter, more focused exercises for SATB ensemble, e.g.,



Thank you!

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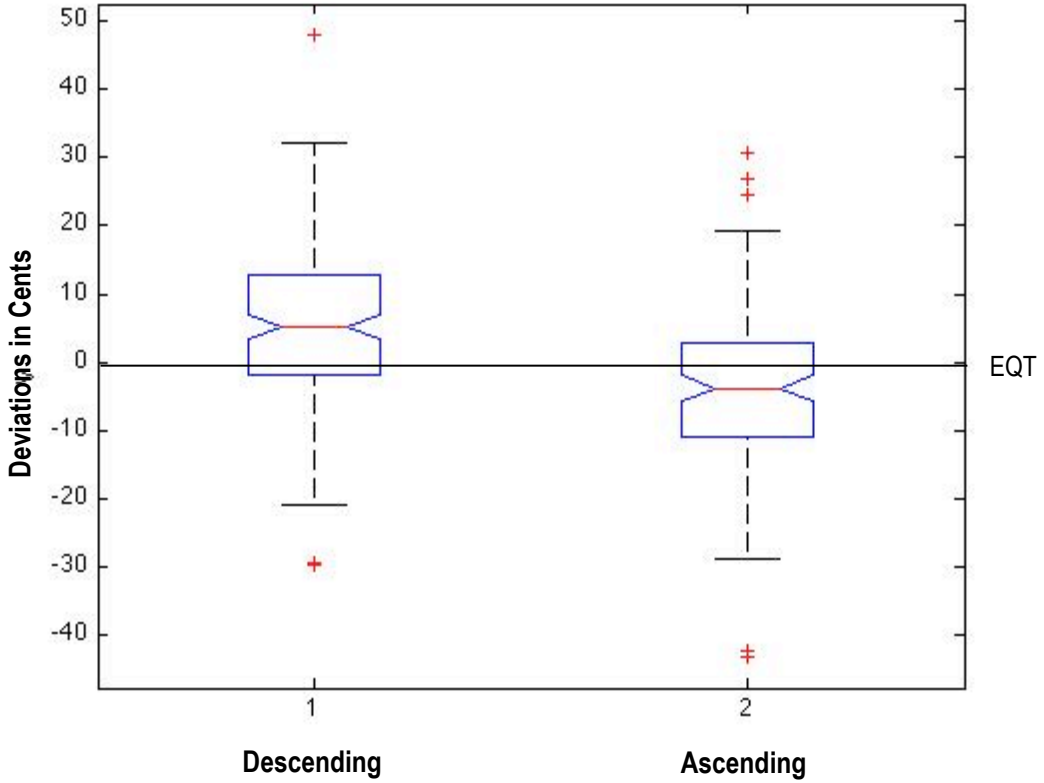
Major Seconds



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