

Horizontal and vertical intonation tendencies in SATB ensembles

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Introduction

Experimental Method

Extraction and Analysis of
Performance Data from Recordings

Discussion of Data

Open Questions

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 influence intonation

Introduction

- ▶ This talk presents work undertaken with a number of collaborators
 - ▶ Ichiro Fujinaga, Jon Wild, and Peter Schubert at McGill University
 - ▶ Michael Mandel at the University of Montreal
 - ▶ Dan Ellis at Columbia University

Experimental Method

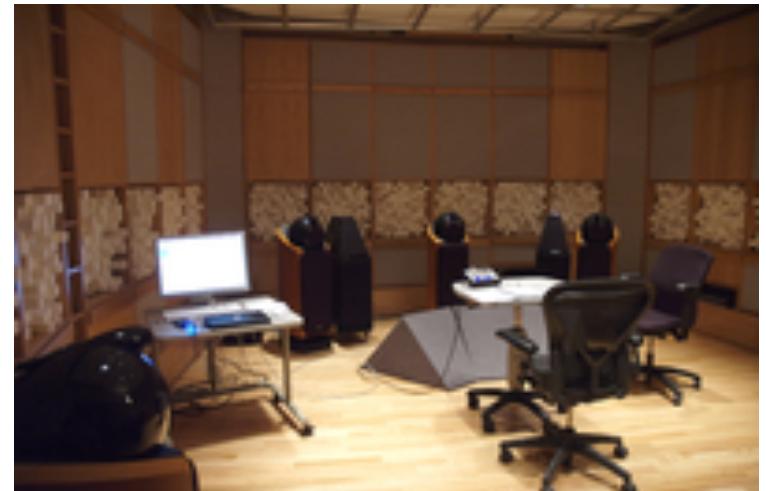
- ▶ Subjects
 - ▶ Ensemble 1 - Semi-professional SATB ensemble
 - ▶ Sing together as section leads at Christ Church Cathedral, Montreal
 - ▶ Ensemble 2 - Professional SATB ensemble
 - ▶ Sing together in the professional Montreal-based ensemble, Viva Voce
 - ▶ Conductor - Peter Schubert (Viva Voce)
- ▶ Materials
 - ▶ Chord progression by Benedetti
 - ▶ 'Es ist ein Ros' entsprungen' by Praetorius

Experimental Method

- ▶ Recording environment and equipment
 - ▶ 4.85m x 4.50m x 3.30m lab at the Center for Interdisciplinary Research in Music Media and Technology with low noise, reflections, and reverberation time (ITU-standard)
 - ▶ Each singer was miked with a cardioid 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





Extraction of Performance Data

- ▶ Labeling 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)
- ▶ Fundamental frequency (F0) estimation for each frame of audio
 - ▶ This research uses the YIN algorithm (de Cheveigné & Kawahara 2002)

Analysis of Performance Data

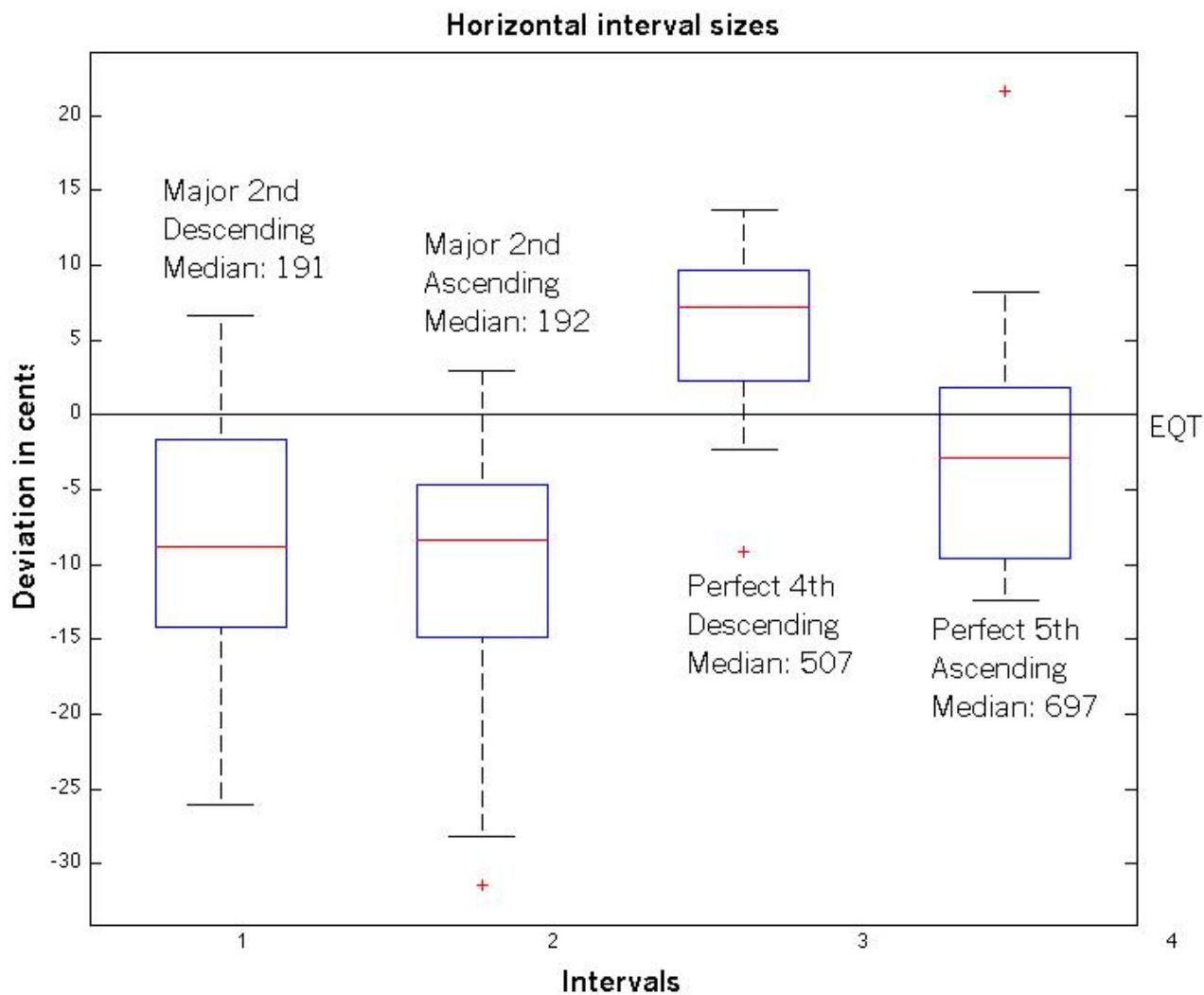
- ▶ Perceived pitch over the duration of each note
 - ▶ Calculated as the geometric mean of the frame-wise F0 estimates (Brown and Vaughn 1996)
- ▶ Evolution of F0 over the duration of the note
 - ▶ Slope (1st Discrete Cosine Transform Coefficient) - whether the singers are gliding up or down into the next note

Benedetti - Example Progression

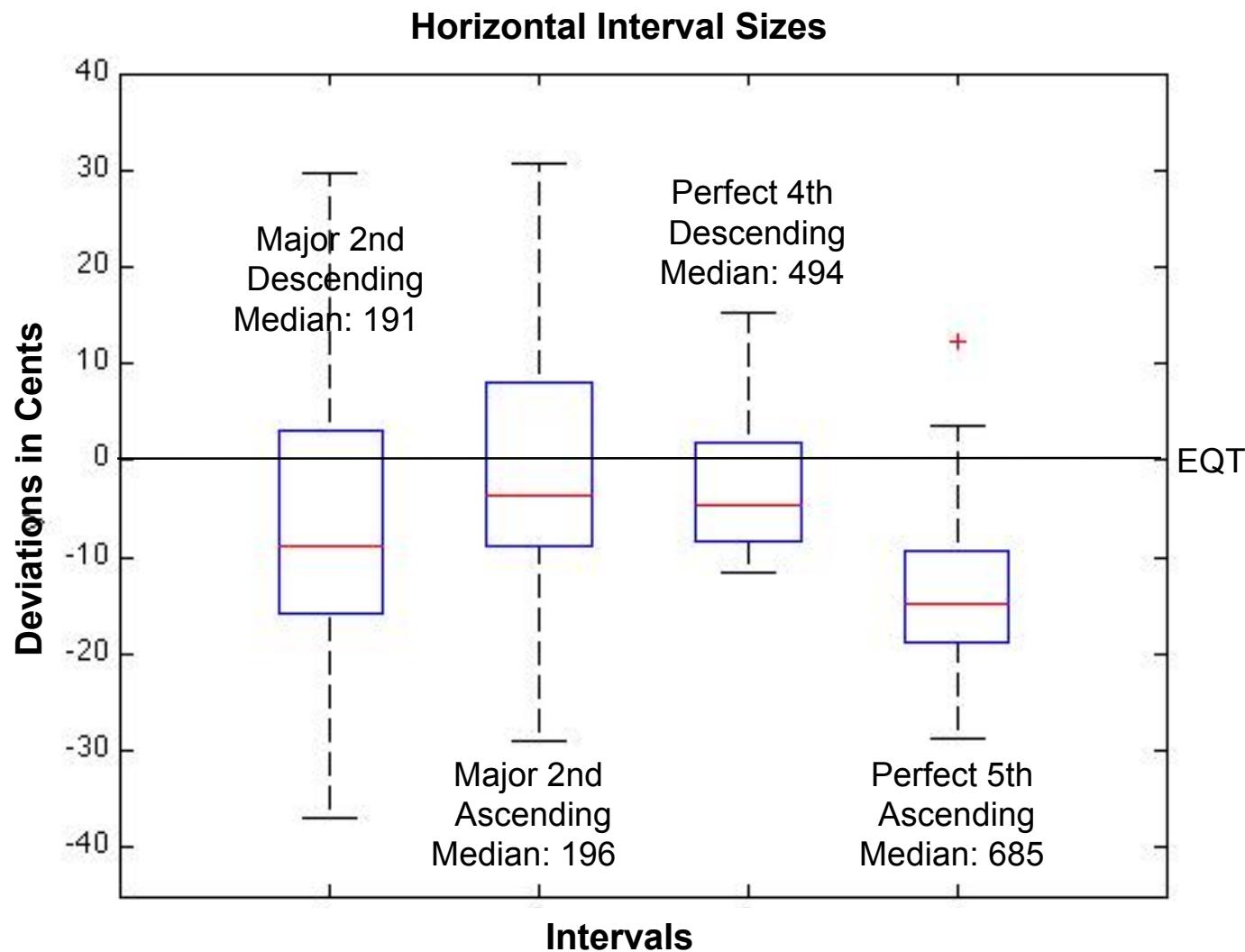
Musical score for Benedetti Example Progression, measures 1-4. The score consists of three staves: Treble, Alto, and Bass. The key signature is one sharp (F#). The time signature is common time (indicated by 'c'). Measure 1: Treble staff has notes on the 2nd, 3rd, and 4th lines; Alto staff has notes on the 3rd and 4th lines; Bass staff has notes on the 2nd and 3rd lines. Measures 2-4: The patterns continue with similar note groupings across all three staves.

Musical score for Benedetti Example Progression, measures 5-8. The score consists of three staves: Treble, Alto, and Bass. The key signature is one sharp (F#). The time signature is common time (indicated by 'c'). Measure 5: Treble staff has notes on the 2nd, 3rd, and 4th lines; Alto staff has notes on the 3rd and 4th lines; Bass staff has notes on the 2nd and 3rd lines. Measures 6-8: The patterns continue with similar note groupings across all three staves.

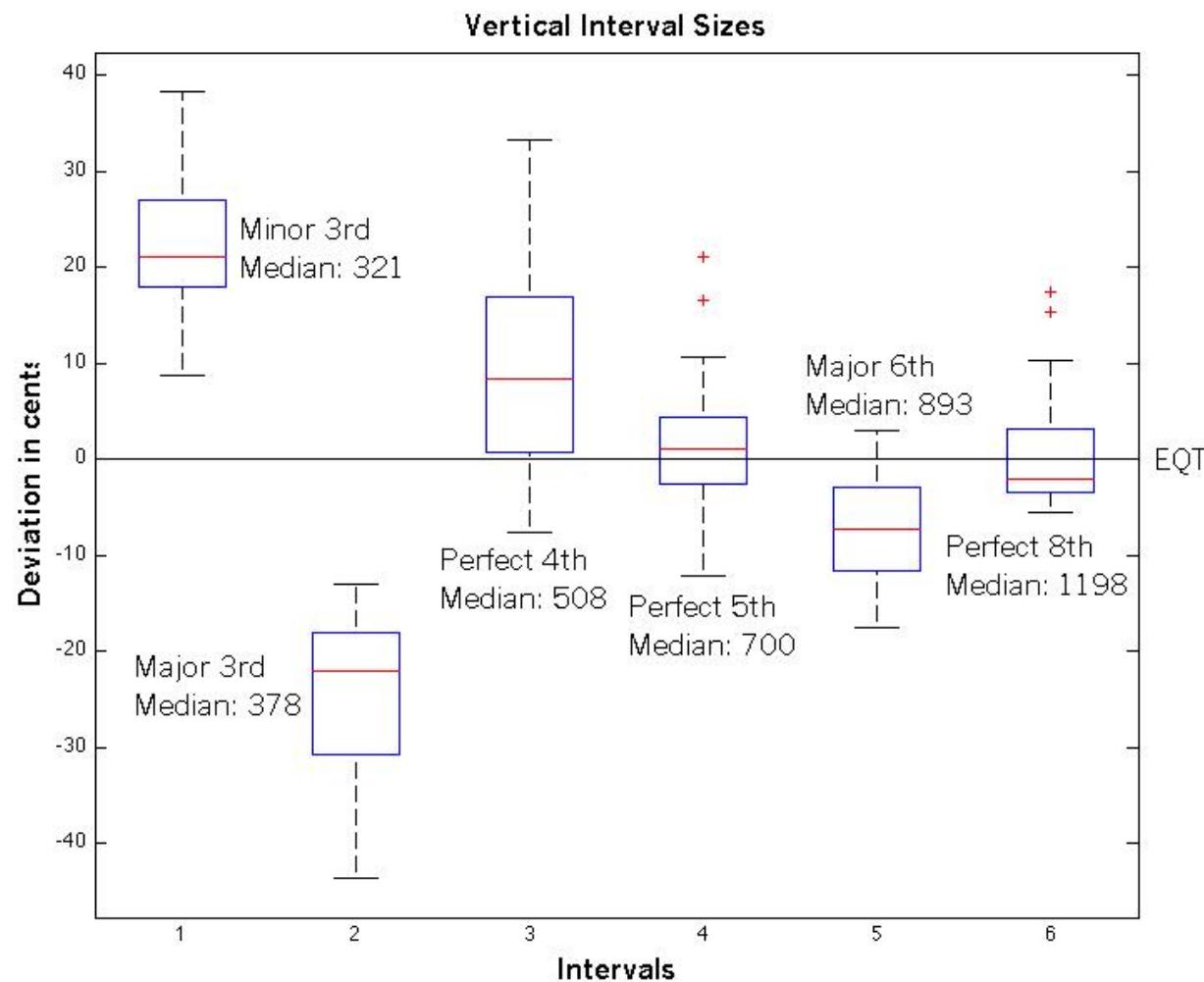
Benedetti (Ensemble 1)



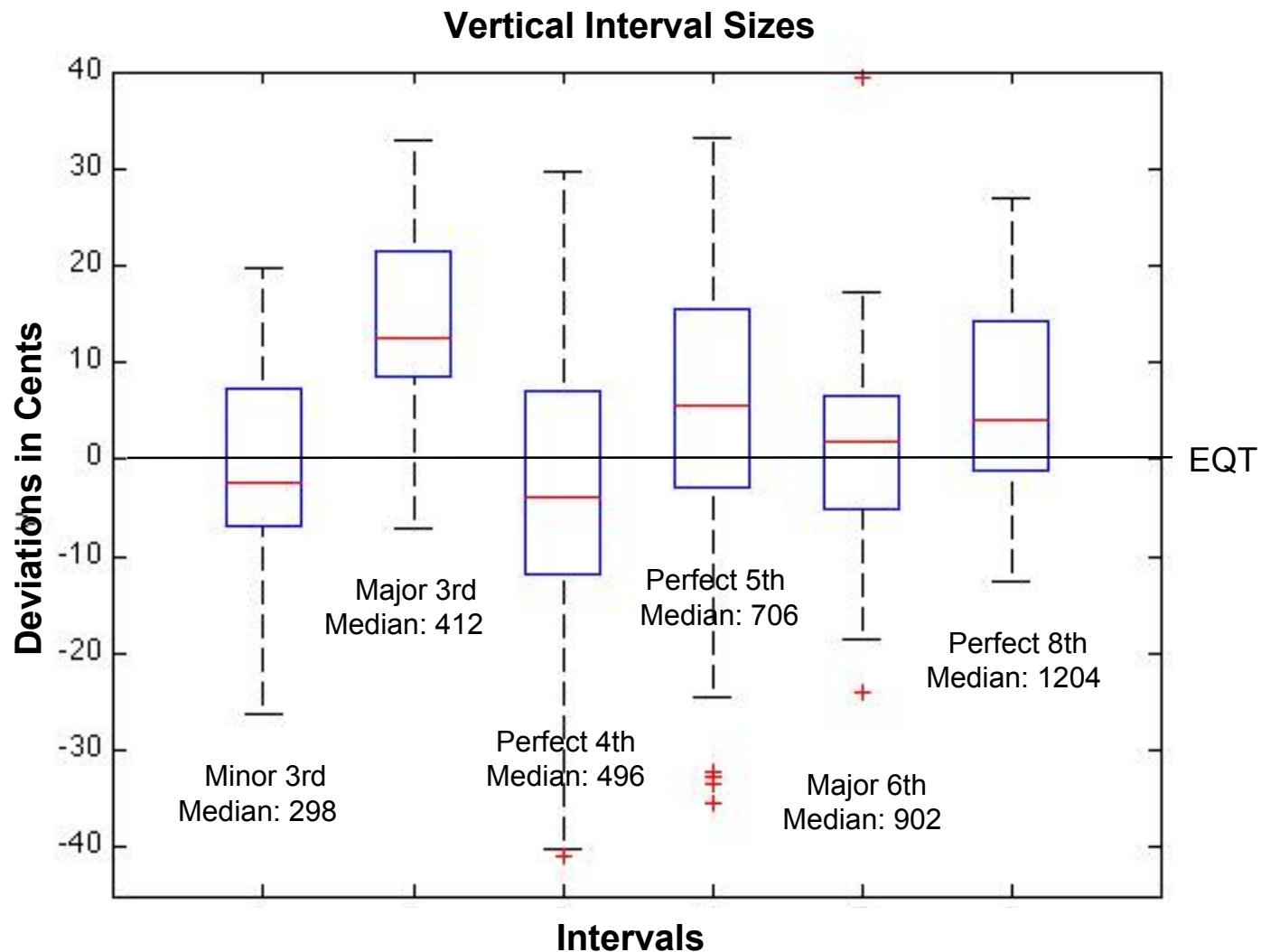
Benedetti (Ensemble 2)



Benedetti (Ensemble 1)



Benedetti (Ensemble 2)



Tuning reference in Benedetti progression

- ▶ Theoretical detuning (tuning to sustained note)

D	E	E	D	D	E	E	D	D	E	E	D	D	E	E	D	D	E	E	D	D	E	E	D	D
0	4	4	22	22	26	26	44	44	48	48	66	66	70	70	88	88								
A	B		A	A	B		B	A	B		A	B		A	B		A	B		A	B		A	
2	6		24	24	28		28	46	50		46	50		68	72		68	72		72	90		90	
D	A	G	D	A	G	D	A	D	A	G	D	A	G	D	A	G	D	A	G	D	A	G	D	
0	2	20	22	24	42	44	46	64	66	68	86	86	88	88										

Musical notation for measures 1-4 of a Benedetti progression. The top staff is in treble clef, G major (no sharps or flats). The middle staff is in bass clef, C major (one sharp). The bottom staff is in bass clef, F major (one sharp). The notation consists of vertical stems with dots indicating pitch levels. Measure 1: Treble staff has dots at 4, 5, 6; Bass staff has dot at 4, stem up. Measure 2: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up. Measure 3: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up. Measure 4: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up.

Musical notation for measures 5-8 of a Benedetti progression. The top staff is in treble clef, G major (no sharps or flats). The middle staff is in bass clef, C major (one sharp). The bottom staff is in bass clef, F major (one sharp). The notation consists of vertical stems with dots indicating pitch levels. Measure 5: Treble staff has dots at 4, 5, 6; Bass staff has dot at 4, stem up. Measure 6: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up. Measure 7: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up. Measure 8: Treble staff has dots at 4, 5, 6; Bass staff has dot at 5, stem up.

Praetorius - Es ist ein Ros' ent sprungen

The musical score consists of three staves of SATB (Soprano, Alto, Tenor, Bass) vocal parts. The lyrics are provided below each staff, and harmonic analysis is indicated by blue boxes under specific measures.

Staff 1:

- Measures 1-2: 1. Es ist ein Ros' ent sprungen
2. Das Rös - lein das ich
- Measures 3-4: sprun - gen mein - e,
Da - von Je - sa
- Measures 5-6: Aus ein - er Wurz
el zart.
ias sagt:

Harmonic Analysis (Staff 1):
Measures 3-4: V vi
Measures 5-6: V I

Staff 2:

- Measures 1-2: Wie uns die Alt-en sung - en,
Ist Ma-ri - a, die Rein - e,
- Measures 3-4: Aus Jes-se kam die Art
Die uns das Blüm - lein bracht.
- Measures 5-6: Und hat ein Blüm-lein bracht,
Aus Gott-es ew' gen Rat

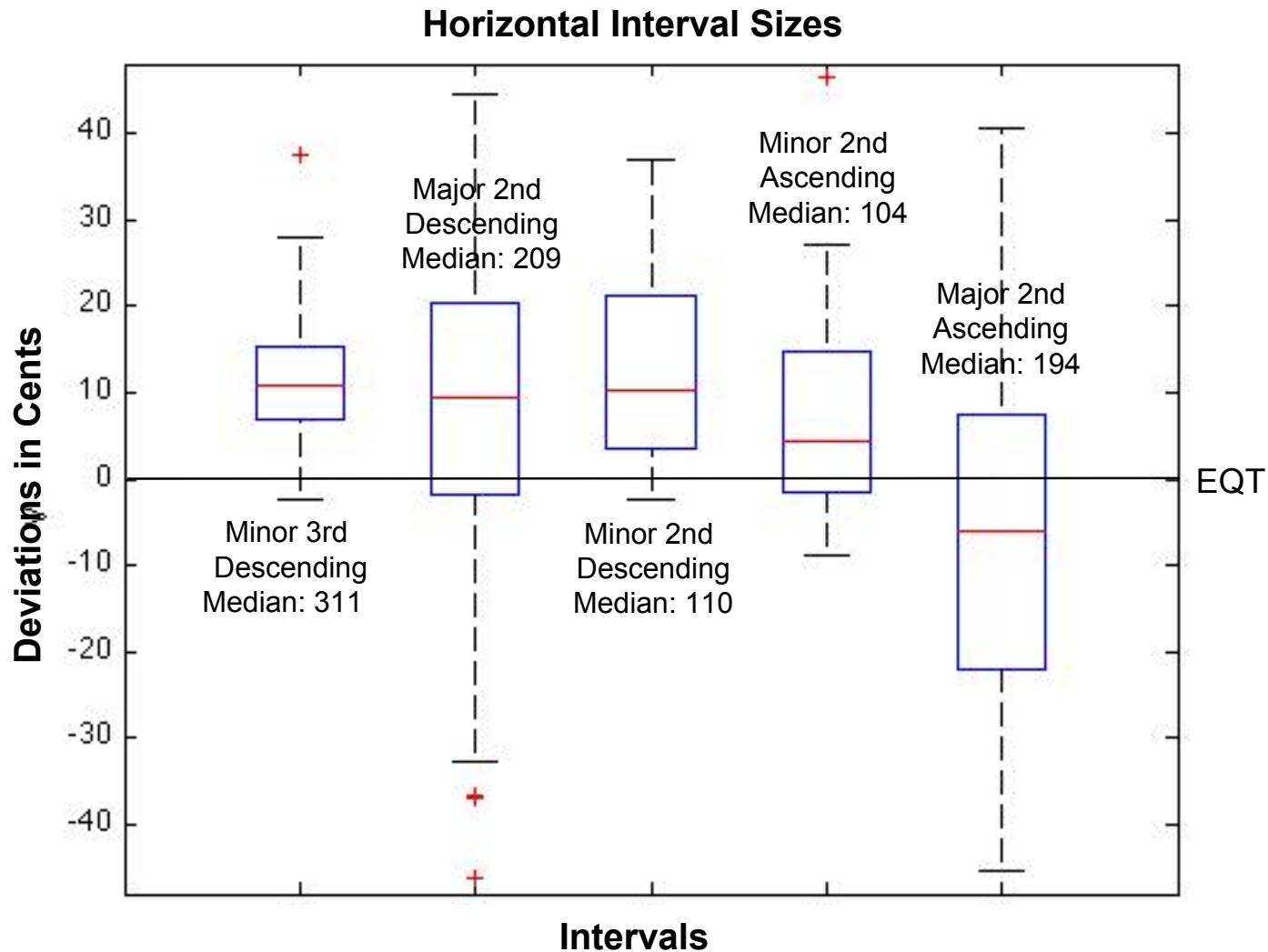
Harmonic Analysis (Staff 2):
Measures 1-2: V vi
Measures 3-4: V I

Staff 3:

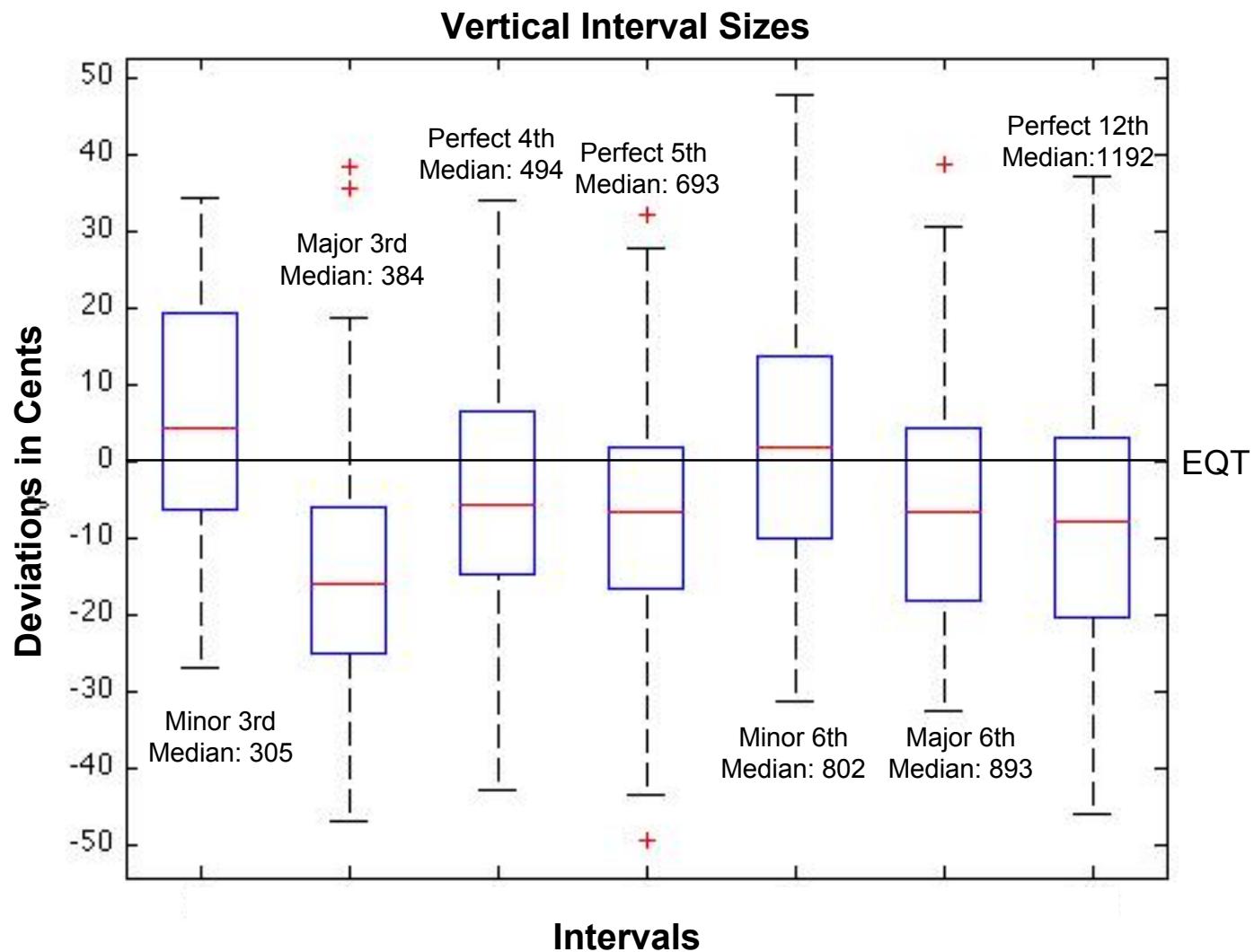
- Measures 1-2: Mitt - en im kalt - en Wint - er,
Hat sie ein Kind ge - bor - en
- Measures 3-4: Wohl zu der halb
Und blieb ein' rein - e Nacht.
Magd.

Harmonic Analysis (Staff 3):
Measures 1-2: V I

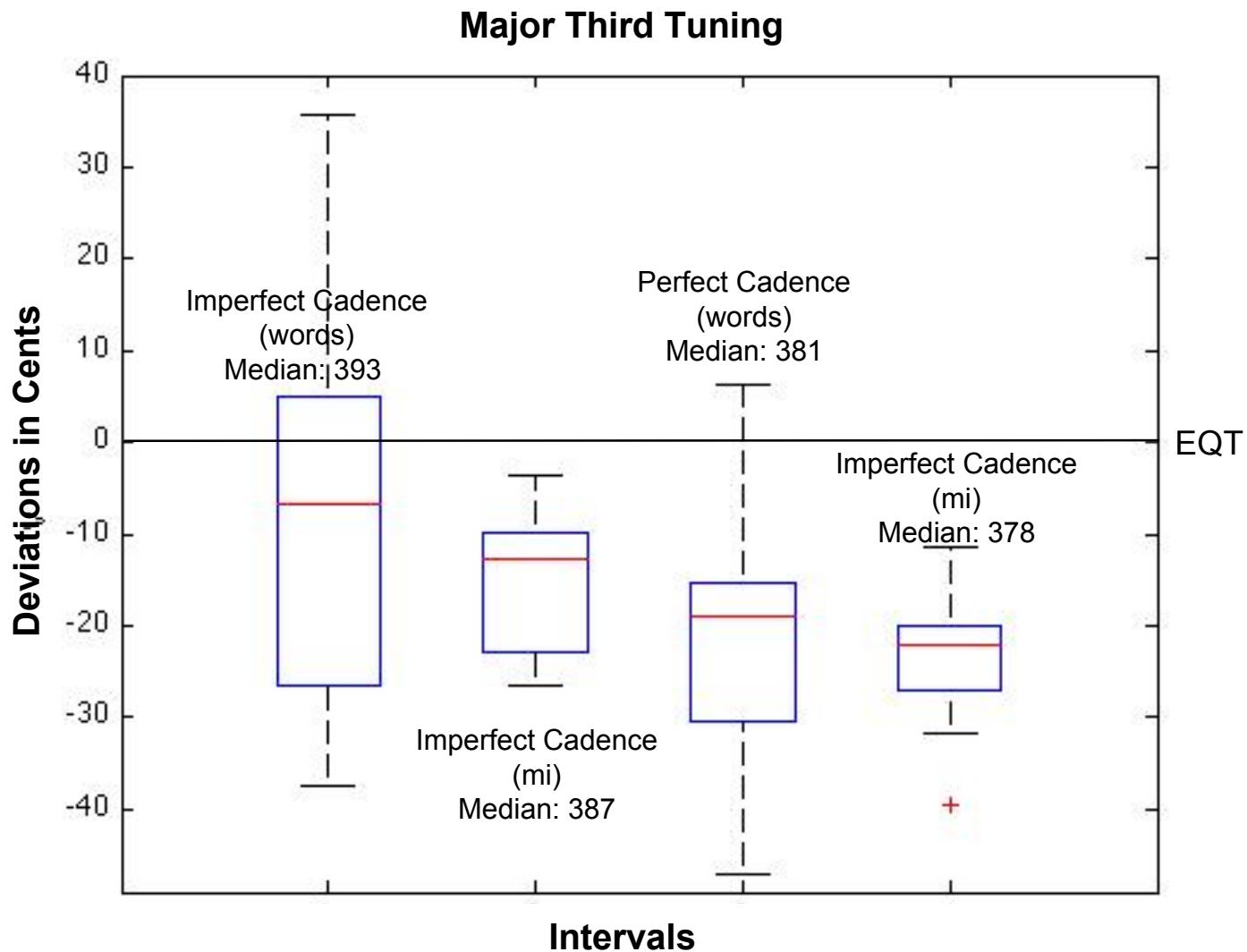
Praetorius (Ensemble 2)



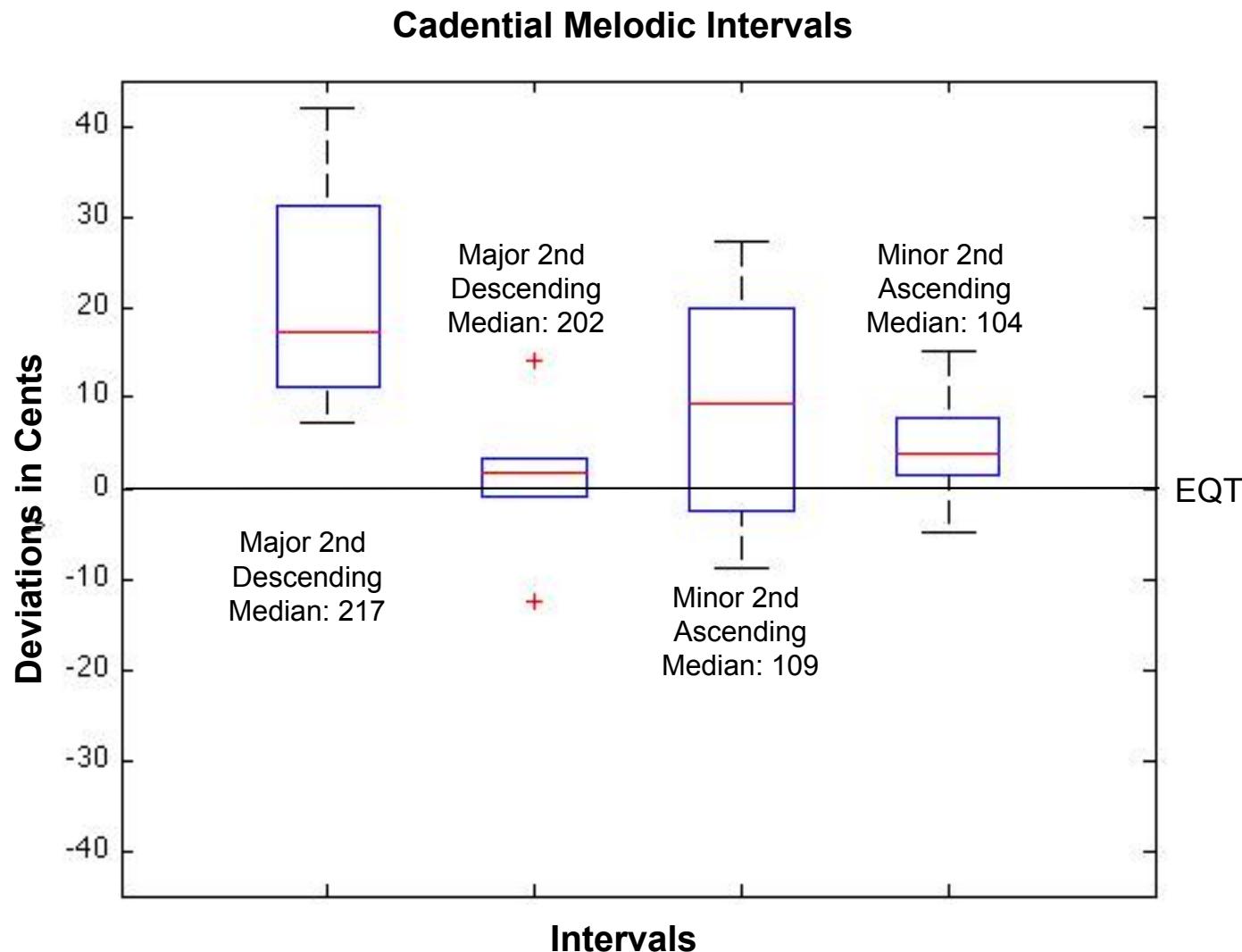
Praetorius (Ensemble 2)



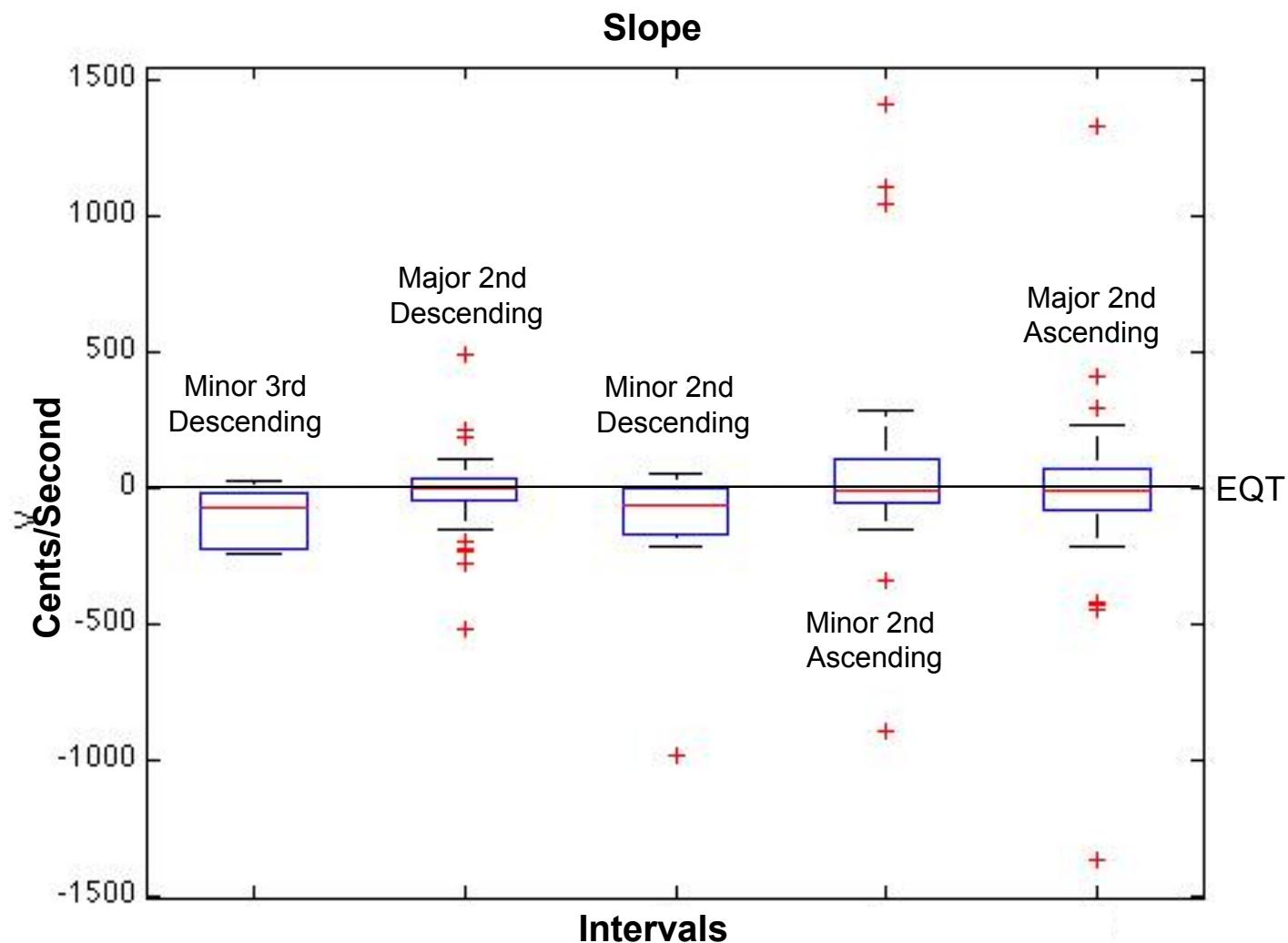
Praetorius (Ensemble 2)



Praetorius (Ensemble 2)



Praetorius (Ensemble 2)



Open Questions

- ▶ Data Analysis Issues
 - ▶ Is there a better model for perceived pitch?
 - ▶ How much variation (in cents) is significant across performances?
 - ▶ How to determine what is typical intonation and what is expressive?
- ▶ Research Questions
 - ▶ How accurately can singers replicate a tuning?
 - ▶ What is the effect of training?
 - ▶ What is the effect of absolute pitch?
 - ▶ What is the effect of more than one singer to a part?
 - ▶ What is the effect of vowel?

Ongoing and Future Work

- ▶ More focused 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

A musical score for SATB ensemble (Soprano, Alto, Tenor, Bass) on four staves. The Soprano staff has three measures. In the first measure, notes at positions 2 and 3 are circled in blue with arrows pointing to them. In the second measure, notes at positions 5 and 6 are circled in blue with arrows pointing to them. In the third measure, notes at positions 4 and 5 are circled in blue with arrows pointing to them. The Alto, Tenor, and Bass staves show sustained notes or simple patterns without circled intervals.

Thank you

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