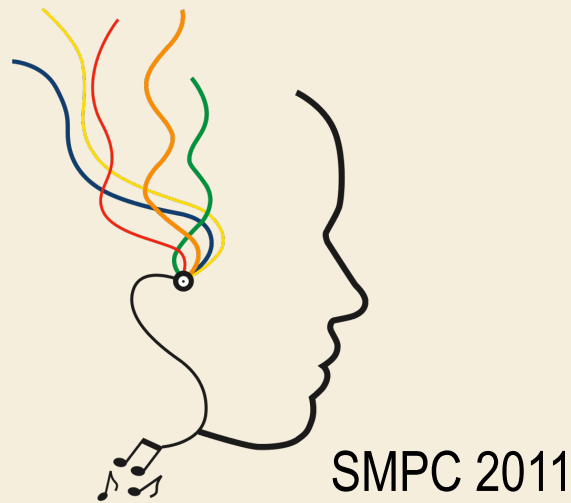


How do singers tune?

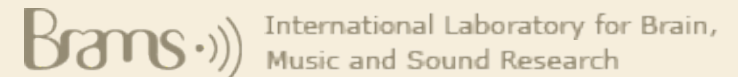


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sciences humaines du Canada



Introduction

Prior Work on Intonation

Intonation Experiments

Conclusions



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Intonation Experiments

Conclusions



Introduction

Prior Work on Intonation

Intonation Experiments

Conclusions



Introduction

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Intonation Experiments

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- Research questions
 - How consistently do singers tune in performance
 - e.g., ascending vs. descending, *a cappella* vs. accompanied, replicating interval sizes across performances
 - How does their tuning relate to idealized tuning systems, such as Just Intonation, Pythagorean tuning, and equal temperament?
- Experiments
 - Solo: six non-professional and professional singers performed Schubert's "Ave Maria" both *a cappella* and with accompaniment
 - Ensemble: three different SATB quartets performed a set of exercises and Praetorius' "Lo how a rose e'er blooming"
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 - Melodic intervals: semitone, whole tone
 - Vertical intervals: m3, M3, P4, TT, P5, m6, M6, m7, and P8



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Prior Work on Intonation

- Schoen (1922) found that in general the accompanied singers he studied were sharper than equal temperament and that notes tended to be flatter when descending and sharper when ascending
- Sundberg, Prame, and Iwarsson (1995) studied professional singers' ability to replicate pitches when singing with accompaniment and found that the average difference between repeated notes was 8 cents
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- Howard (2007) studied two a cappella SATB quartets and found that the ensembles used non-equal temperament with a tendency toward, though not full compliance with Just-Intonation
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Intonation Experiments

- Solo Intonation Experiment
 - 6 undergraduate vocal majors and 6 professional singers
 - Franz Schubert's "Ave Maria"
 - sung *a cappella* and with accompaniment
- Ensemble Experiment
 - 1 semi-professional quartet (pilot) and 2 professional quartets (lab and church)
 - Exercises composed by Jonathan Wild and Peter Schubert, where semitones and whole tones occur in different contexts
 - Chord progression by Giambattista Benedetti
 - Michael Praetorius' "Lo how a rose e'er blooming"



Intonation Experiments

The image displays a musical score for the song "Ave Maria" by Franz Schubert, specifically the first system of the vocal line. The score is written in G major (one sharp) and 3/4 time. It consists of five staves of music. The lyrics are written below the notes. The score is annotated with two types of markings: solid circles and dashed boxes. Solid circles are placed around specific notes or groups of notes, indicating semitones that were analyzed. Dashed boxes are placed around groups of notes, indicating whole tones that were analyzed. The lyrics are: "A - ve Ma - ri - a, Gra - ti - a ple - na Ma - ri - a gra - ti - a ple - na A - ve A - ve Do - mi - nus, Do - mi - nus te - cum Be - ne - dic - ta tu in mu - li - e - ri - bus et be - ne - di - ctus, et be - ne - dic - tus fru - ctus ven - tris, ven - tris tu - i Je - sus, A - ve Ma - ri - a!". The markings are distributed across the score, with some notes circled and others boxed, and some notes being both circled and boxed. A small "LT" marking is visible under the first "ple" in the second staff.

“Ave Maria” (Franz Schubert)

○ Semitones Analyzed □ Whole tones analyzed



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Intonation Experiments

Semitone Exercises (Jonathan Wild)

1 2 3 4 5 6

S

A

T

B

Exercise 1: Soprano starts on G4, moves to A4 (circled), then B4 (circled). Exercise 2: Soprano starts on A4, moves to B4 (circled), then C5 (circled). Exercise 3: Soprano starts on B4, moves to C5 (circled), then D5 (circled). Exercise 4: Soprano starts on C5, moves to D5 (circled), then E5 (circled). Exercise 5: Soprano starts on D5, moves to E5 (circled), then F#5 (circled). Exercise 6: Soprano starts on E5, moves to F#5 (circled), then G5 (circled).

7 8 9 10 11 12

S

A

T

B

Exercise 7: Soprano starts on F#5, moves to G5 (circled), then A5 (circled). Exercise 8: Soprano starts on G5, moves to A5 (circled), then B5 (circled). Exercise 9: Soprano starts on A5, moves to B5 (circled), then C6 (circled). Exercise 10: Soprano starts on B5, moves to C6 (circled), then D6 (circled). Exercise 11: Soprano starts on C6, moves to D6 (circled), then E6 (circled). Exercise 12: Soprano starts on D6, moves to E6 (circled), then F#6 (circled).

13 14 15 16 17 18

S

A

T

B

Exercise 13: Soprano starts on E6, moves to F#6 (circled), then G6 (circled). Exercise 14: Soprano starts on F#6, moves to G6 (circled), then A6 (circled). Exercise 15: Soprano starts on G6, moves to A6 (circled), then B6 (circled). Exercise 16: Soprano starts on A6, moves to B6 (circled), then C7 (circled). Exercise 17: Soprano starts on B6, moves to C7 (circled), then D7 (circled). Exercise 18: Soprano starts on C7, moves to D7 (circled), then E7 (circled).

19 20 21 22 23

S

A

T

B

Exercise 19: Soprano starts on D7, moves to E7 (circled), then F#7 (circled). Exercise 20: Soprano starts on E7, moves to F#7 (circled), then G7 (circled). Exercise 21: Soprano starts on F#7, moves to G7 (circled), then A7 (circled). Exercise 22: Soprano starts on G7, moves to A7 (circled), then B7 (circled). Exercise 23: Soprano starts on A7, moves to B7 (circled), then C8 (circled).

24 25 26 27

S

A

T

B

Exercise 24: Soprano starts on B7, moves to C8 (circled), then D8 (circled). Exercise 25: Soprano starts on C8, moves to D8 (circled), then E8 (circled). Exercise 26: Soprano starts on D8, moves to E8 (circled), then F#8 (circled). Exercise 27: Soprano starts on E8, moves to F#8 (circled), then G8 (circled).



Intonation Experiments

The image displays a musical score for a four-part vocal exercise, 'Whole Tone Exercises' by Peter Schubert. The score is presented in three systems, each containing four staves for Soprano (S), Alto (A), Tenor (T), and Bass (B). The exercises are numbered 1 through 18. The notation is in treble and bass clefs, with various accidentals (sharps, flats, naturals) indicating the specific pitches. The exercises are designed to explore intonation, with some measures featuring boxed notes to highlight specific intervals or chords. The first system contains measures 1-6, the second system contains measures 7-12, and the third system contains measures 13-18.

Whole Tone Exercises (Peter Schubert)

Intonation Experiments

The image shows a musical score for a piece titled "Repeated Progression" by Giambattista Benedetti. The score is written for a single melodic line, likely for a voice or a single instrument, in treble and bass clefs. The key signature is one sharp (F#), and the time signature is common time (C). The score consists of 12 measures. A blue box highlights the first four measures, which are:
1. D4 (quarter), E4 (quarter), F#4 (quarter), G4 (quarter)
2. A4 (quarter), B4 (quarter), C5 (quarter), B4 (quarter)
3. A4 (quarter), G4 (quarter), F#4 (quarter), E4 (quarter)
4. D4 (quarter), C4 (quarter), B3 (quarter), A3 (quarter)
The remaining eight measures continue the progression with various intervals and accidentals, including a tritone (F#4 to C5) and a diminished fifth (B4 to F#4).

Repeated Progression (Giambattista Benedetti)



Intonation Experiments

Score system 1 (measures 1-6) for Soprano (S), Alto (A), Tenor (T), and Bass (B). The Soprano part includes a *LT* (Liedertune) marking. Circles indicate semitones analyzed, and dashed boxes indicate whole tones analyzed.

Score system 2 (measures 7-12) for Soprano (S), Alto (A), Tenor (T), and Bass (B). The Soprano part includes a *LT* (Liedertune) marking. Circles indicate semitones analyzed, and dashed boxes indicate whole tones analyzed.

Score system 3 (measures 13-18) for Soprano (S), Alto (A), Tenor (T), and Bass (B). The Soprano part includes a *LT* (Liedertune) marking. Circles indicate semitones analyzed, and dashed boxes indicate whole tones analyzed.

○ Semitones Analyzed □ Whole tones analyzed

Score system 1 (measures 1-6) for Soprano (S), Alto (A), Tenor (T), and Bass (B). Vertical bars indicate whole tones analyzed. Roman numerals V, vi, and I are present below the Bass staff.

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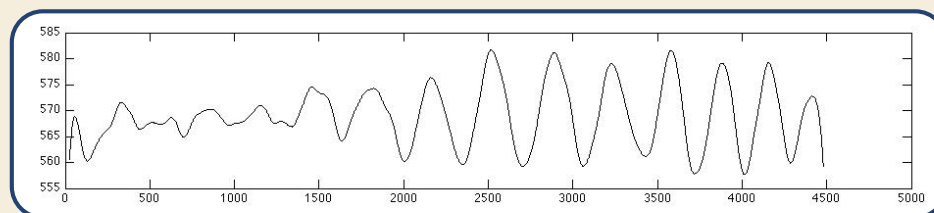
“Lo’ How a Rose e’er blooming” (Michael Praetorius)

Intonation Experiments

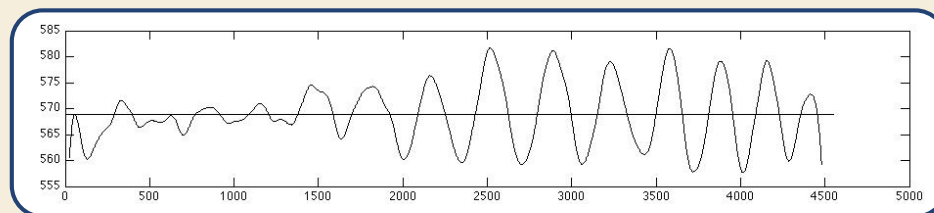
Identify Note Onsets and Offsets



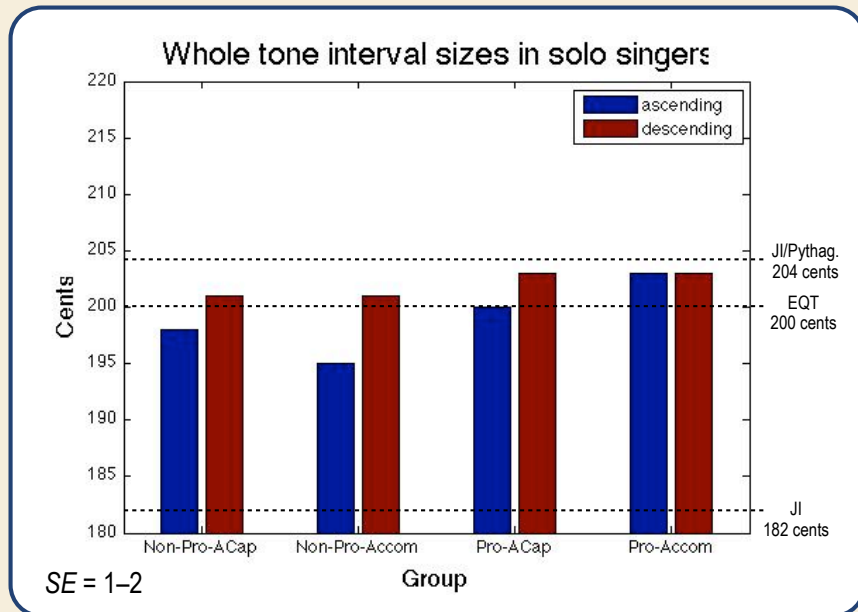
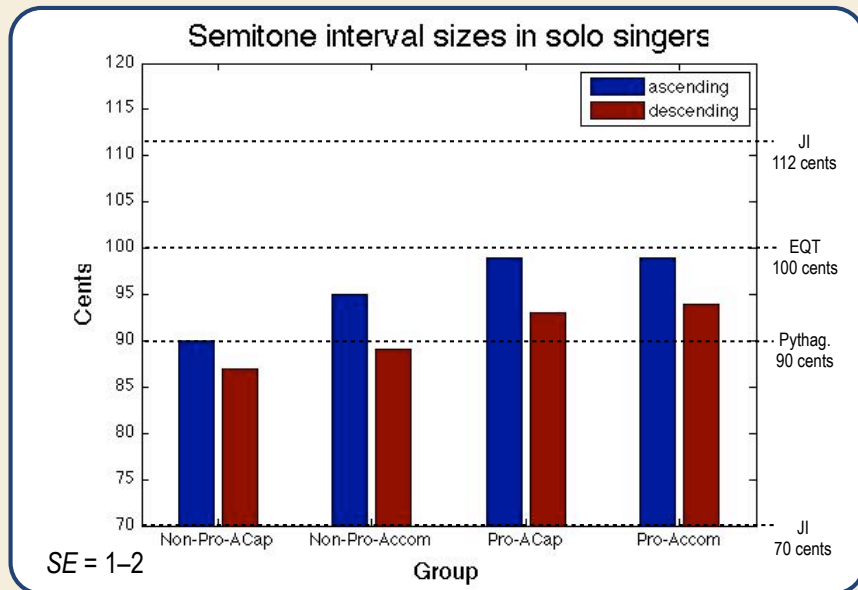
Fundamental Frequency (F0) Estimation



Perceived Pitch

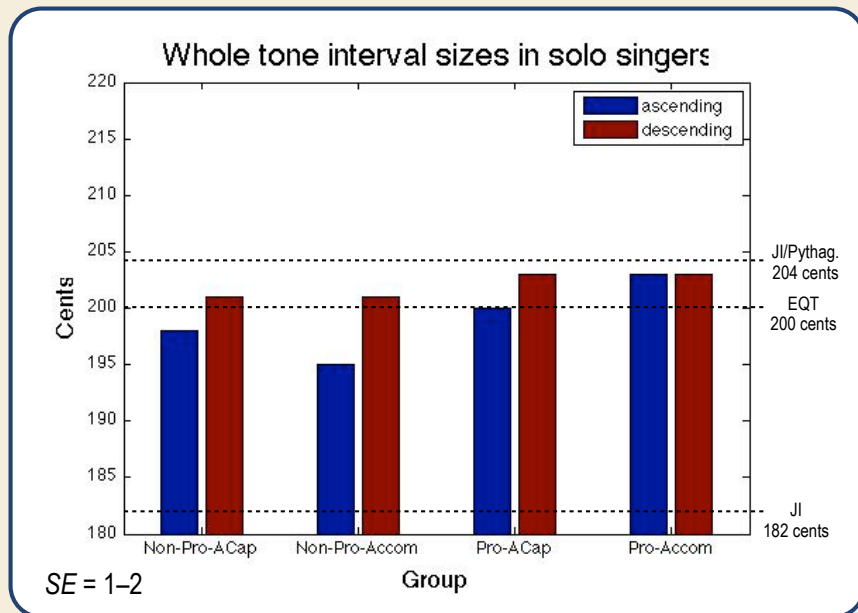
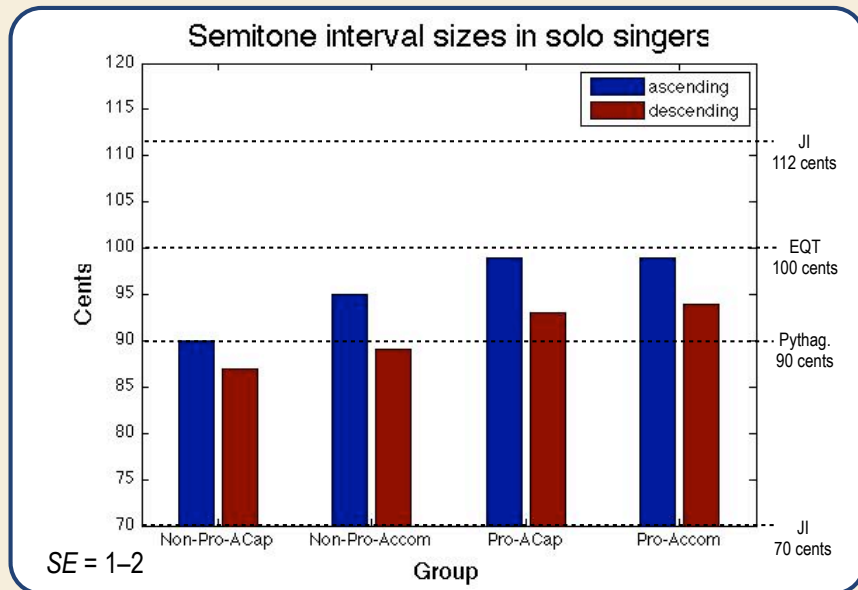


Intonation Experiments - Solo



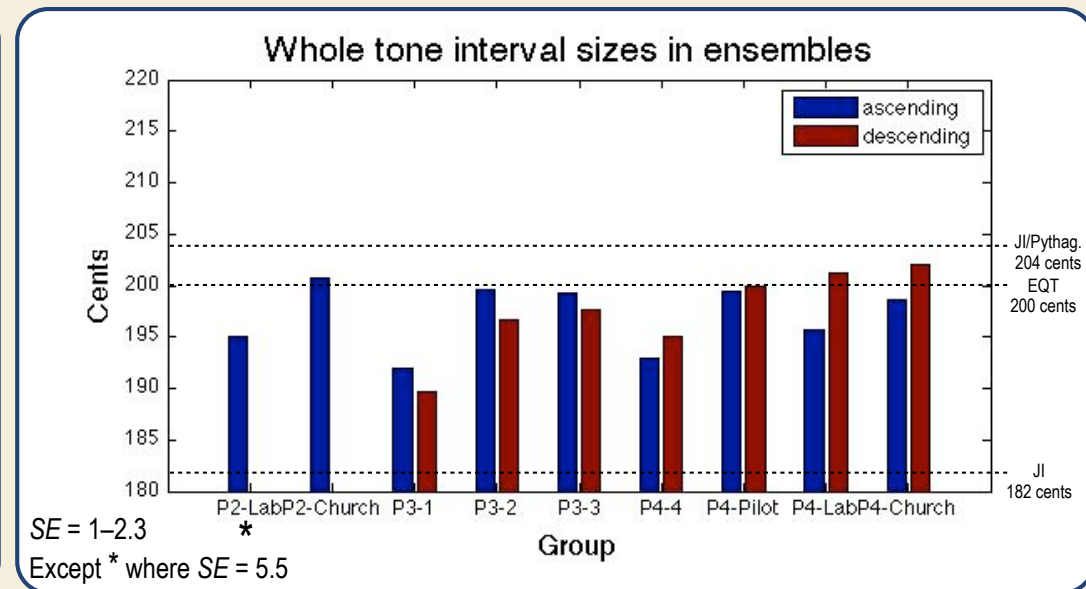
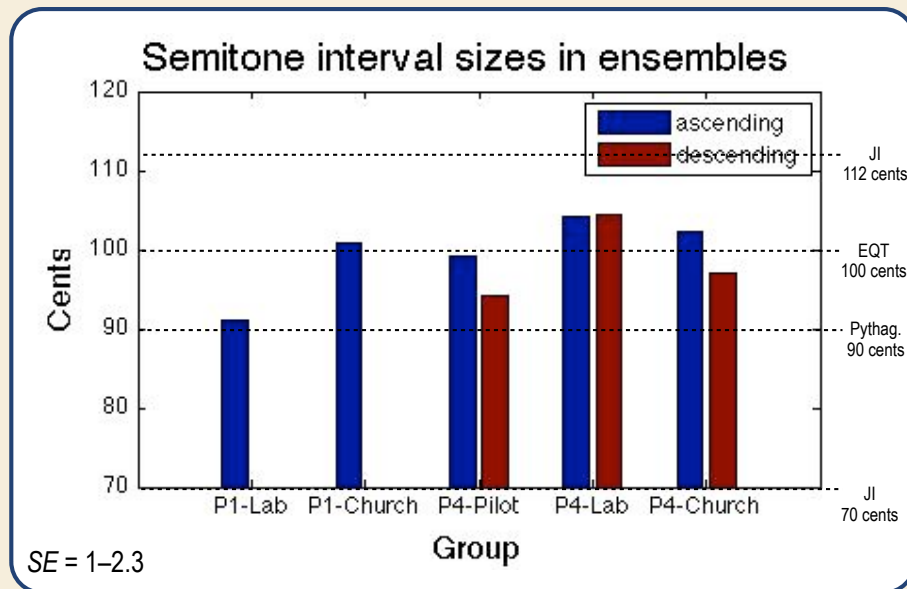
- Adherence to fixed systems
- Semitones
 - mean of pros' ascending semitones closest to equal temperament
 - mean of non-pros' semitones (ascending and descending) and pros' descending semitones closest to Pythagorean
- Whole tones
 - mean of pro's whole tones closest to Just Intonation/Pythagorean tuning (except for ascending *a cappella* whole tones)
 - mean of non-pro's whole tones (and pro's ascending *a cappella* whole tones) were closest to equal temperament

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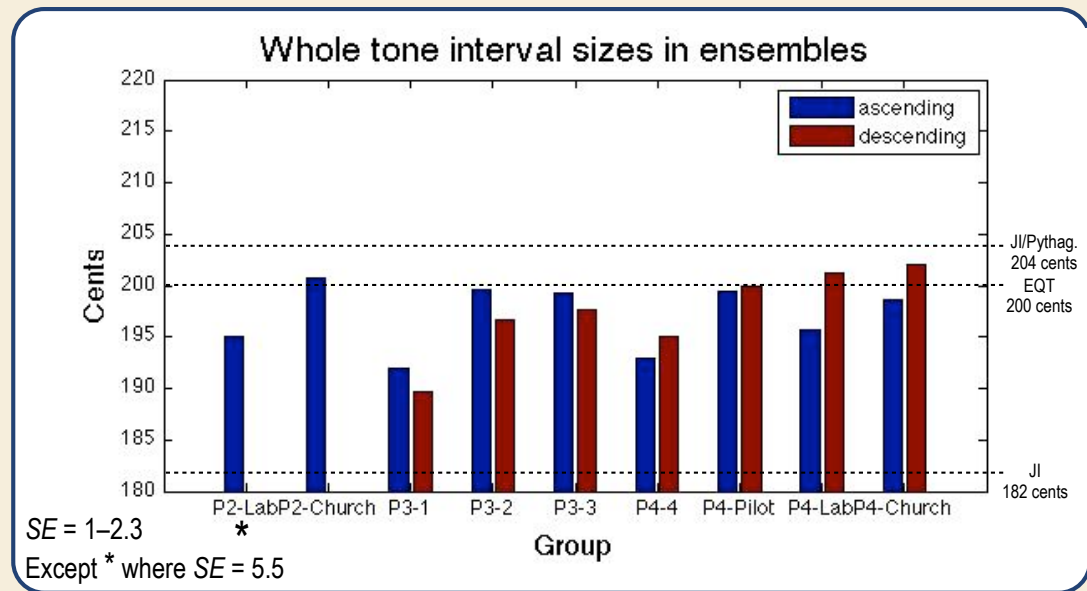
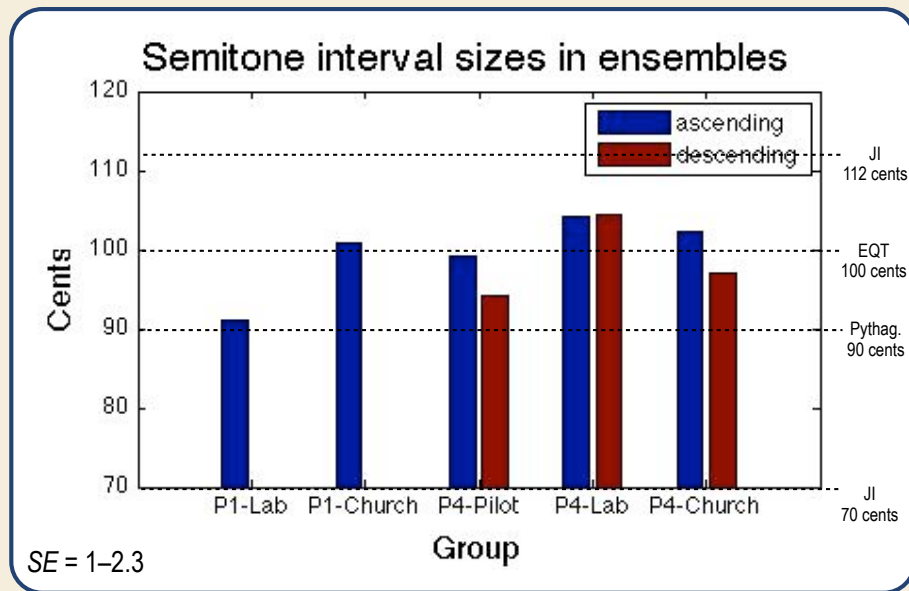
Intonation Experiments - Ensembles



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 - Lab ensemble in part one was closest to Pythagorean
 - Whole tones: means of the majority of ascending and descending whole tones were closest to equal temperament
 - Ensemble 1's whole tones in Part Three were between 200 EQT and 182 JI tuning



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Intonation Experiments

- When there was a difference of more than a couple of cents between idealized Equal Temperament and Just Intonation

- most ensembles' means were closer to equal temperament (except for some ensembles' m6, M6, and m7)

	Pythagorean	5-limit Just Intonation	Equal Temperament
	Cents	Cents	Cents
m3	294	316	300
M3	408	386	400
P4	498	498	500
TT	588	590	600
	612	610	
P5	702	702	700
m6	792	814	800
M6	905	884	900
m7	996	1018	1000
P8	1200	1200	1200

- However, when cadential context was taken into account in the Praetorius, a *t*-test ($p < 0.05$) revealed that the tuning was closer to Just Intonation in cadential contexts than non-cadential contexts



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	Pilot	Lab	Church
Cadence	14.356	14.108	14.261
Non-Cadence	17.027	16.631	17.254

Mean deviation in cents from idealized Just Intonation tunings



Intonation Experiment

		Previous Findings	Current Findings
Adherence to a Fixed System	<i>Solo</i>	Schoen (1922): <i>sharper than EQT</i> Prame (1997): <i>deviation from EQT</i>	<i>closest to EQT</i> <i>(except non-pro semitones)</i>
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Ascending vs Descending	<i>Solo</i>	Schoen (1922): <i>both descending and ascending intervals larger than EQT</i>	<i>descending semitones smaller*</i> <i>descending whole tone larger*</i>

* when the effect was significant ($p < 0.01$)



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Accompanied vs. a cappella	<i>Solo</i>	Vurma (2010): <i>detuning of accompanying synthesized voices didn't significantly effect intonation</i>	<i>non-professionals showed an effect for semitone tuning but no effect for whole tone tuning</i>

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Replicating Pitches	<i>Solo</i>	Sundberg, Prame, and Iwarsson (1995): <i>8 cents average deviation</i>	<i>11 cents for non-professionals</i> <i>12 cents for professionals</i>



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Just Noticeable Difference for Detecting Mistunings		Lynch et al. (1991): for melodic intervals: 10 cents (experienced musicians) Vurma (2010): for two-part intervals: 20–40 cents (experienced musicians)	



Conclusions

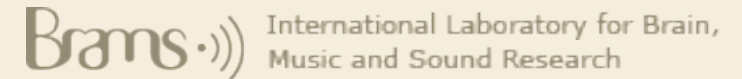
- How consistently did the singers tune in performance?
 - In the solo experiment there were some significant effects for accompaniment and ascending vs. descending
 - In the ensemble experiment there were some significant effects for ascending vs. descending
- How did their tuning relate to idealized tuning systems?
 - Melodic intervals: the singers did not conform exactly to equal temperament but were closest to it than any other system
 - Vertical intervals: overall they were closest to equal temperament but tended more towards Just Intonation in cadential contexts



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 - Melodic intervals: the singers did not conform exactly to equal temperament but were closest to it than any other system
 - Vertical intervals: overall they were closest to equal temperament but tended more towards Just Intonation in cadential contexts



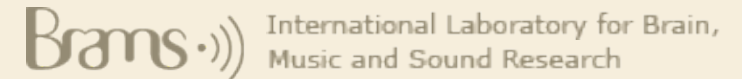


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Thank you!



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