How do we perceive vocal pitch accuracy during singing?

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Université de Liège

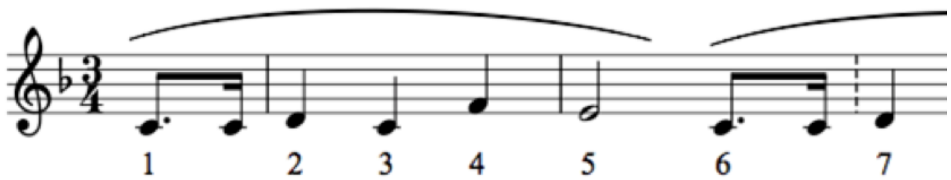
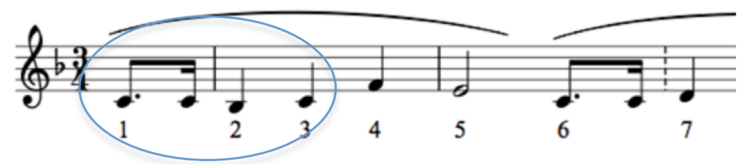
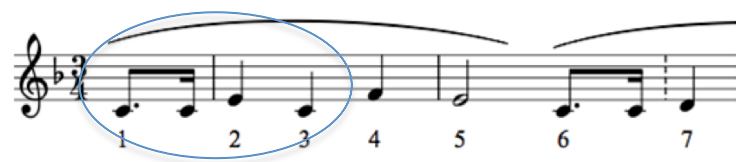
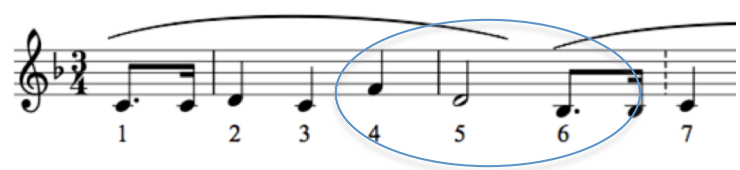
the Auditory Perception & Action Lab

In tune?

Definition

- Singing (a melody)
  - → Perception of musical errors
- Between the tones
  - → Perception of pitch categories
- Within the tones
  - → Acoustic description of pitch fluctuations
  - → Effect on pitch accuracy perception

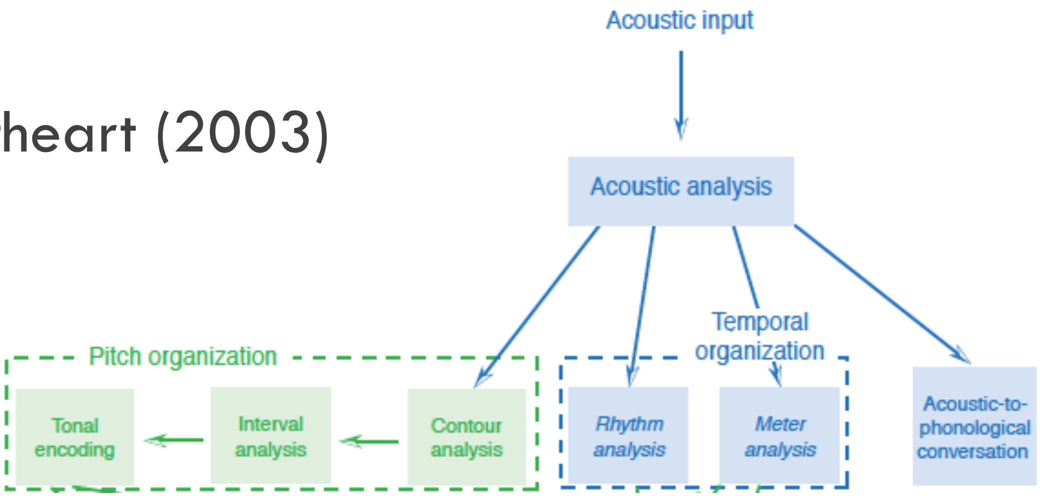
Perception of musical errors

Error types

Contour error

Interval error

Tonality error

Error types

- Young age
  - Categorisation of contour errors:10 months (Ferland & Mendelson, 1989)
  - Discrimination of tonality and intervals (Hannon & Trainor, 2007; Gooding & Stanley, 2001; Plantinga & Trainor, 2005; Stalinski et al., 2008)
- Errors perceived by adults

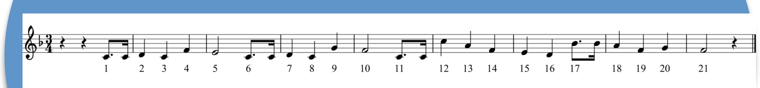
Dowling & Fujitani, 1970; Edworthy, 1985; Stalinski et al., 2008; Trainor & Trehub, 1992

Peretz & Cortheart (2003)



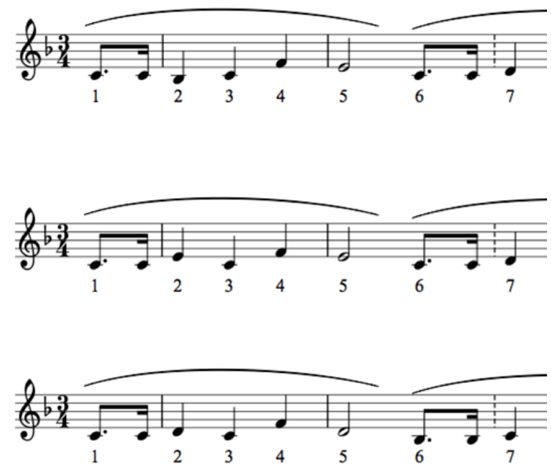
Method

166 performances



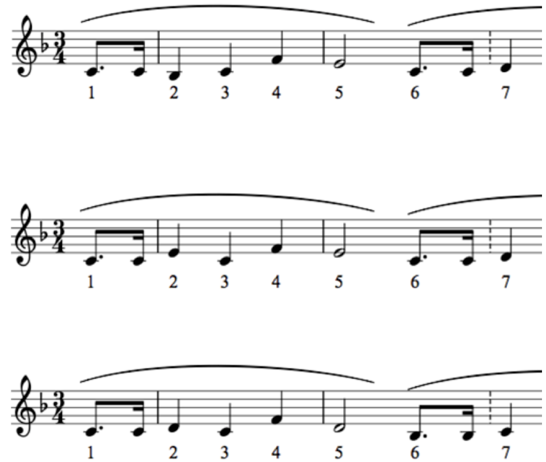
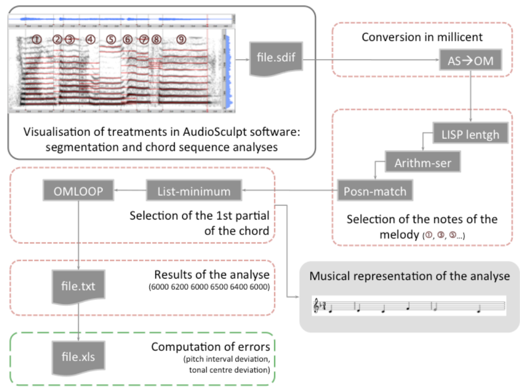
http://sldr.org/sldr000774/en

Computer assisted method

3 criteria

18 Judges

1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9

Out of tune — In tune

Computer assisted method



Manual segmentation

AudioSculpt (Ircam)

F0 information

AudioSculpt and OpenMusic (Ircam)

Quantification of errors

Excel (Microsoft)

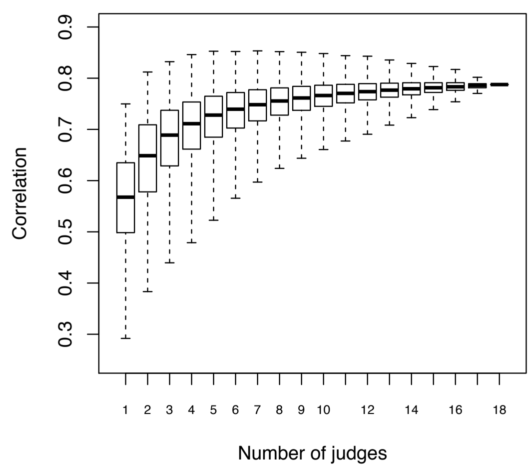
Larrouy-Maestri, P., & Morsomme, D. (in press). Criteria and tools for objectively analysing the vocal accuracy of a popular song. *Logopedics Phoniatrics Vocology.*

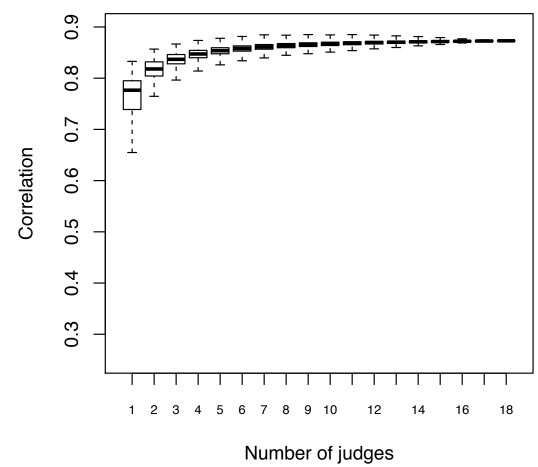
Participants

	Experts	Non experts
n	18	18
Gender	8 women	8 women
Age	$M = 29.89$; $SD = 14.47$	$M = 33.06$; $SD = 9.57$
Expertise	5 professional musicians 5 professional singers 4 music students 4 speech therapists	___
Musical or vocal practice	OK	___
Audiometry	___	OK
MBEA (Peretz et al., 2003)	___	OK
Production task « Happy Birthday »	___	OK

Results

	Non experts	Experts
Model	$F(3,165) = 104.44; p < .01$	$F(3,165) = 231.51; p < .01$
% variance	66%	81%
Criteria	Interval deviation	Interval deviation Tonality modulations





Larrouy-Maestri, P., Lévêque, Y., Schön, D., Giovanni, A., & Morsomme, D. (2013). The evaluation of singing voice accuracy: A comparison between subjective and objective methods. *Journal of Voice*.

Conclusions

Perception of musical errors

- Perception of pitch accuracy based on
  - interval errors for all
  - + tonality for music experts
- Better evaluation for small deviation

Between the tones

For now

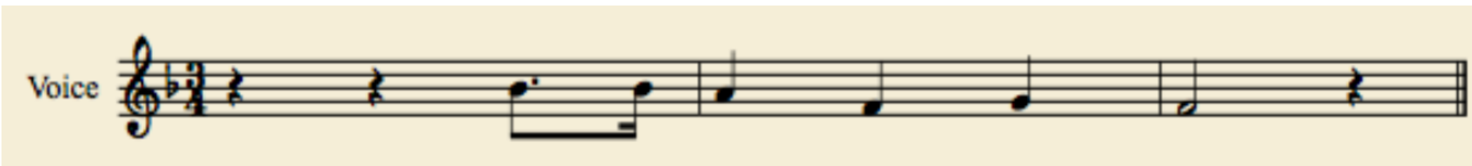
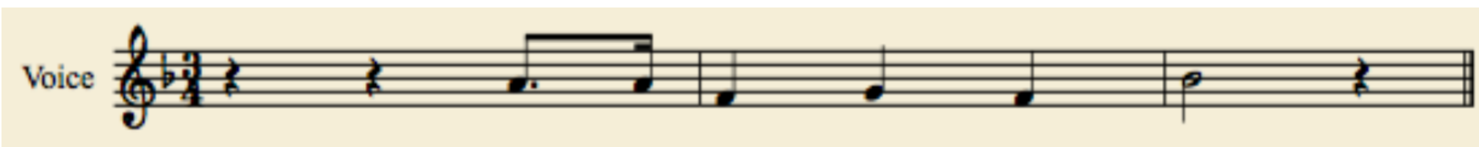
- Pitch discrimination
  - http://www.musicianbrain.com/pitchtest/
  - http://tonometric.com/adaptivepitch/
- In a melodic context
  - Semitone (100 cents) Berkowska & Dalla Bella, 2009 ; Dalla Bella et al., 2007, 2009a, 2009b ; Pfordresher & al., 2007, 2009, 2010
  - Quartertone (50 cents) Hutchins & Peretz; 2012 ; Hutchins, Roquet, & Peretz, 2012 ; Pfordresher & Mantell, 2014

→ **Which threshold in a melodic context?**

→ **Effect of familiarity?** Yes (Kinney, 2009) No (Warrier & Zatorre, 2002)

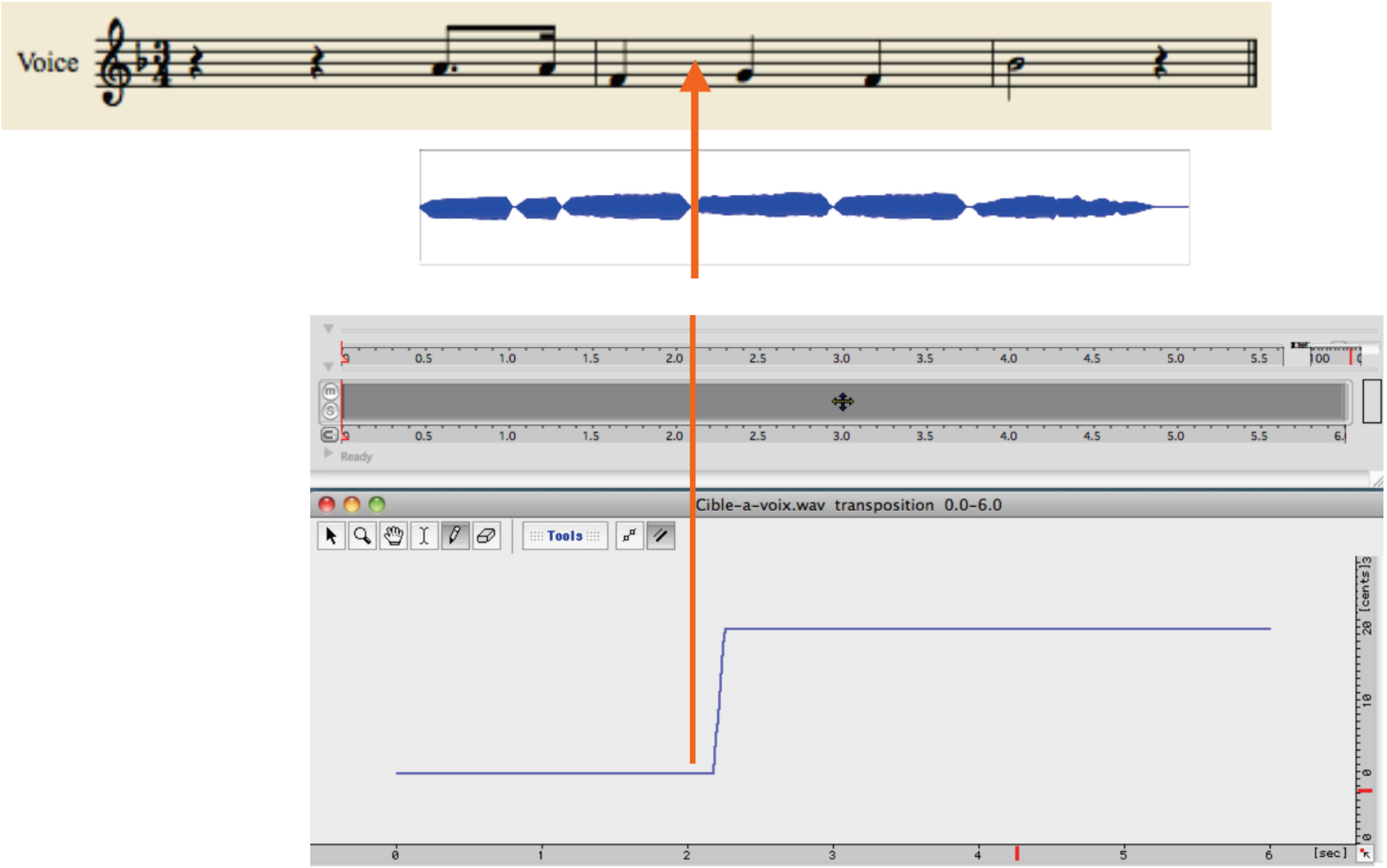
→ **Effect of the direction of the error?**

Material

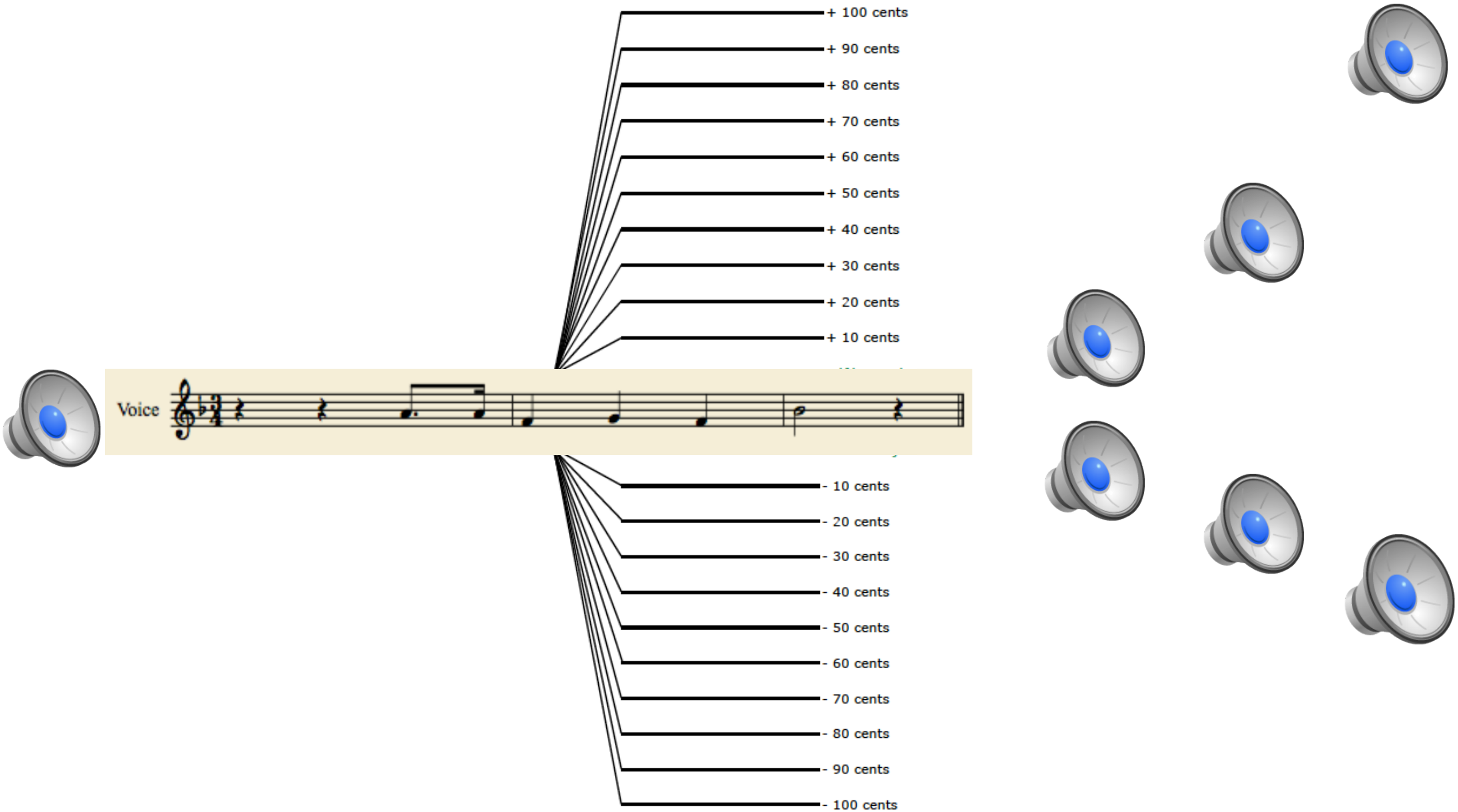
- Two melodies



- Familiarity ?
  - Online questionnaire
  - 399 participants from 13 to 70 years old (M = 29.81)
  - $t(398) = 20.92$, $p < .001$

Material


Voice
Cible-a-voix.wav transposition 0.0-6.0
Tools
Ready
[cents]
[sec]

Material

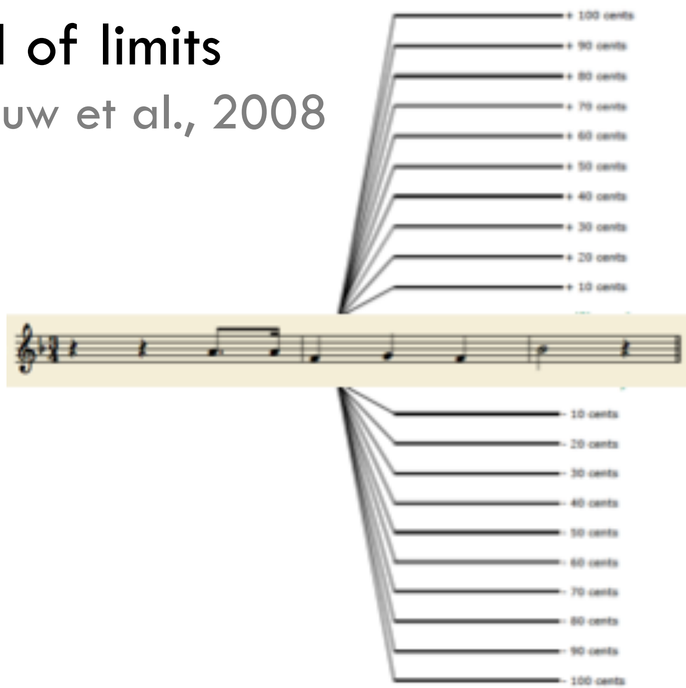

+ 100 cents
+ 90 cents
+ 80 cents
+ 70 cents
+ 60 cents
+ 50 cents
+ 40 cents
+ 30 cents
+ 20 cents
+ 10 cents
Voice
- 10 cents
- 20 cents
- 30 cents
- 40 cents
- 50 cents
- 60 cents
- 70 cents
- 80 cents
- 90 cents
- 100 cents

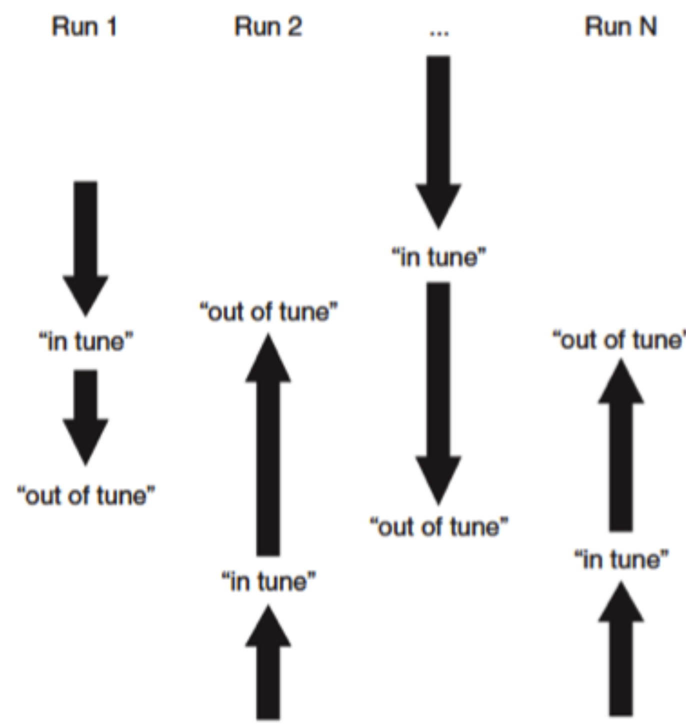
Participants and procedure

- 30 non musicians (*M* = 21.33 years; *SD* = 2.45)
- Two times with 8 to 15 days in between

Method of limits

van Besouw et al., 2008





- Comparison test-retest

Familiar melody

	Test M(SE)	Retest M(SE)	R Pearson	Comparison
Enlargement	15.43 (1.24)	17.33 (1.12)	.69**	T(29) = 2.04, ns
Compression	26.07 (1.98)	23.40 (1.66)	.82**	T(29) = 2.36*
Tolerance	41.50 (2.50)	40.73 (1.89)	.82**	T(29) = 0.54, ns

Non familiar melody

	Test M(SE)	Retest M(SE)	R Pearson	Comparison
Enlargement	17.20 (1.33)	17.80 (1.12)	.68**	T(29) = 0.60, ns
Compression	25.30 (1.84)	22.23 (1.46)	.84**	T(29) = 3.03**
Tolerance	42.50 (2.05)	40.03 (1.95)	.80**	T(29) = 1.93, ns

→ **Good intra-judges reliability**

→ **Learning effect?**

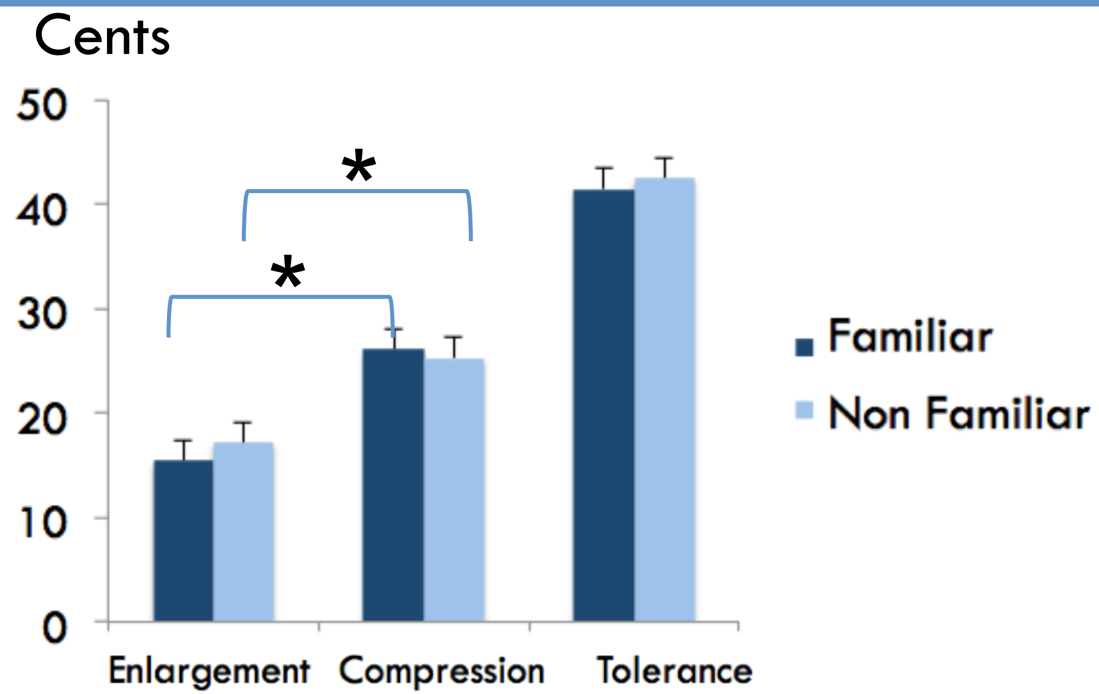
- Correlation matrix between the judges

(% of significant r (0.8 to 1) between the judges)

	Familiar	Non Familiar
Test	66.44	71.03
Retest	72.64	71.72

→ **Good inter-judges reliability**

→ **Learning effect?**



→ **No effect of familiarity**

- Familiar : $t = -4.94$, $p < .001$
- Non Familiar : $t = -3.27$, $p = .003$

→ **Threshold depends on the direction of the error**

Larrouy-Maestri, P., Blanckaert, E.., & Morsomme, D. (in preparation). How tolerant are we when evaluating melodies ?

Conclusions

Between the tones

- Less tolerant than what we thought
  - < quarter-tone
- Particularly for enlarged intervals
  - Effect of the error direction
- Whatever the melody
  - No effect of familiarity

Within the tones

For now

- Complex signal (Sundberg, 2013)
- Effects of pitch fluctuation on pitch perception (Castellengo, 1994; d'Alessandro & Castellengo, 1994; Hutchins et al., 2012; van Besouw et al., 2008)
- The case of operatic voices (Larrouy-Maestri, Magis, & Morsomme, 2014, in press a, in press b)

➔ **What is a "normal" voice?**

➔ **Perception of "non ideal" sung performances ?**

Descriptive model of pitch fluctuation

- Modification of the temporal adaptation model
  (Large, Fink & Kelso, 2002)
- Too many parameters to be taken seriously as a cognitive model!
- …just designed to get relevant summary statistics for pitch fluctuations

Descriptive model of pitch fluctuation

Pitch at time *t*
Comes from “start” fluctuations and “**end**” fluctuations influencing an ***asym***ptote

$$Pitch_t = Y_{s_t} + Y_{e_t} + asym$$

$$Y_{s_t} = [A_s * \exp(-b_s t) * \cos(2\pi f_s t + \theta_s)]$$

A_s: Beginning perturbation

$-b_s$: Approach to asymptote

f_s: Oscillation around target (overshoot)

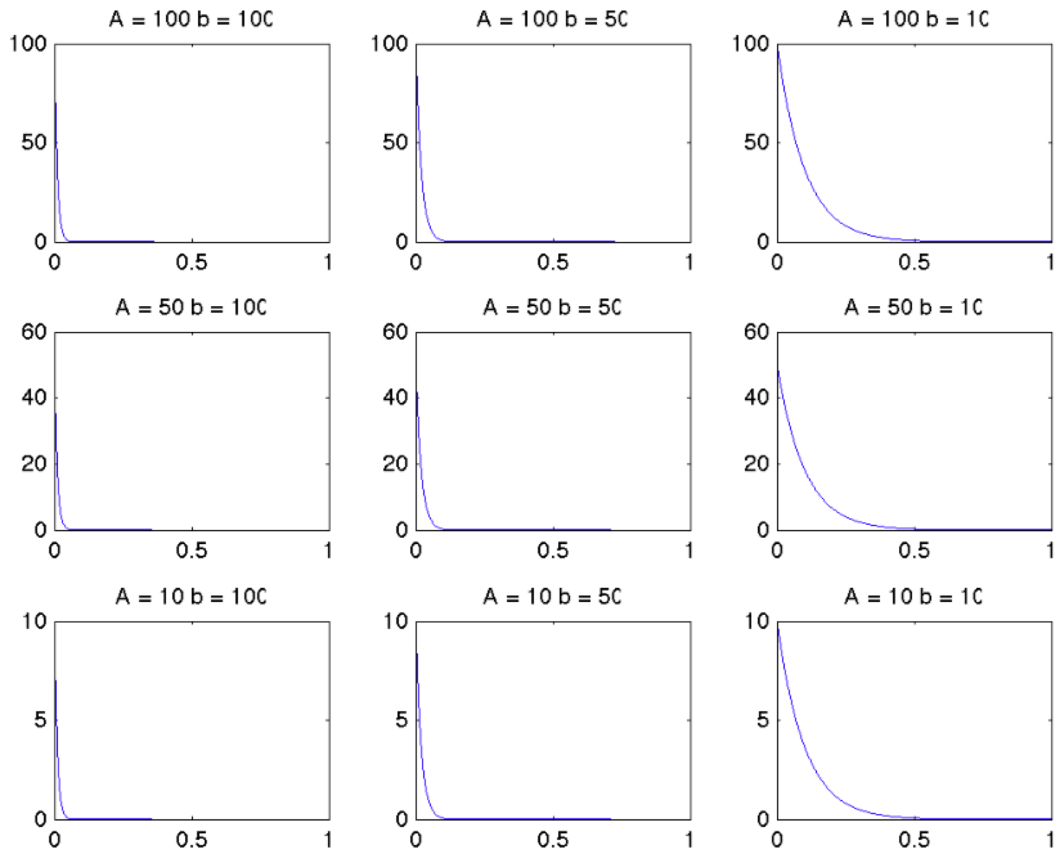
θ_s: Approach is down (= 0) Or up (= pi)

Y_{e_t}: Similar to starting fluctuations, except
-Time values mirror reversed
-New and adjusted parameters

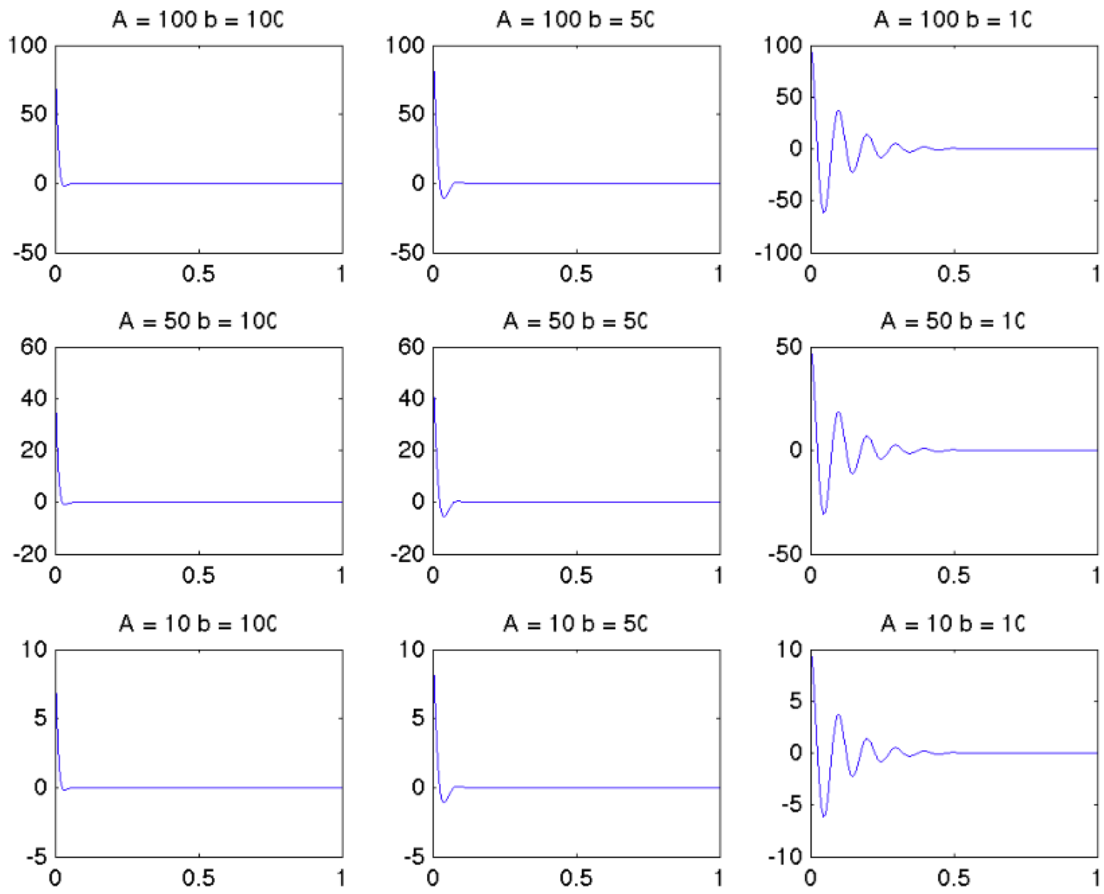
A (comforting?) note on parameters

- The only fitted parameters are
  - Rate of approach: b_s, b_e
  - Oscillation around target: f_s, f_e
- Others come from data
  - *asym:* from middle portion of tone (median)
  - *A* values from difference of beginning to *asym*
  - A_e values from difference of end to *asym*
  - θ is effectively a ‘toggle’

Starting fluctuations: magnitude (A) and rate of approach (b)

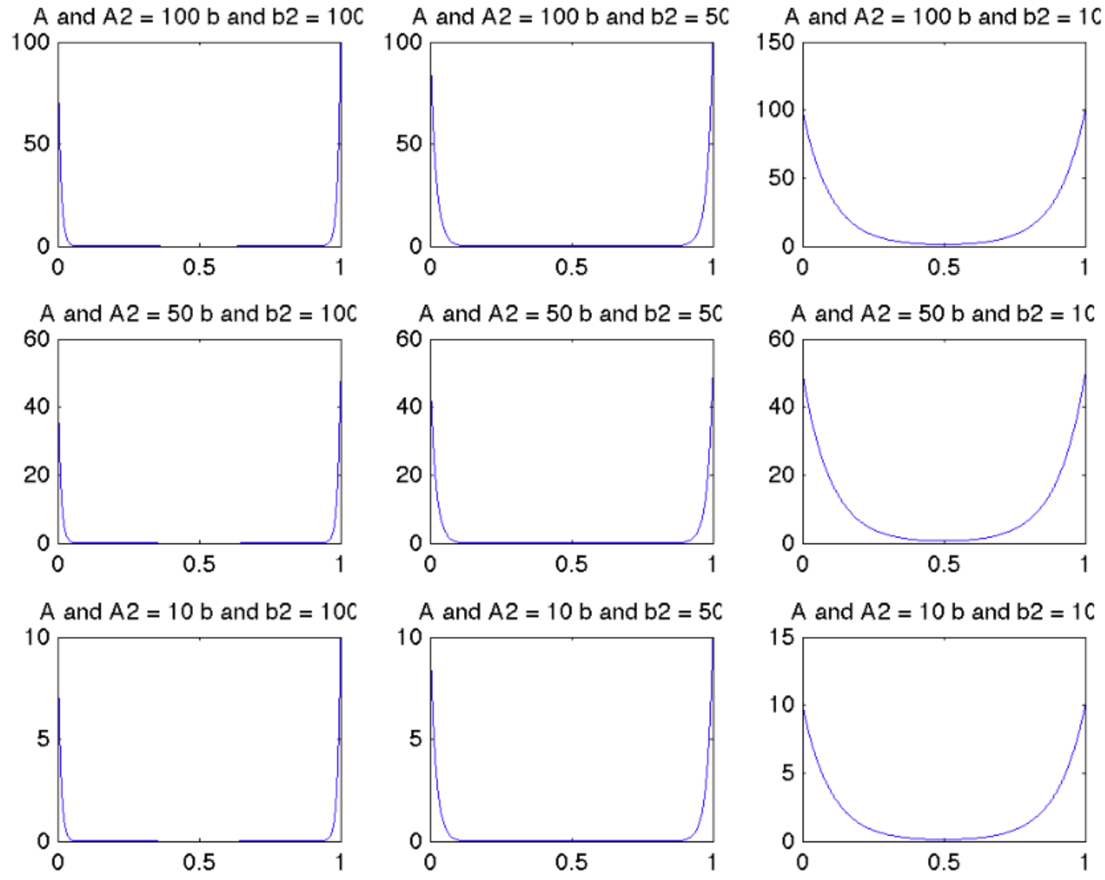


Oscillation around approach (f = 10)



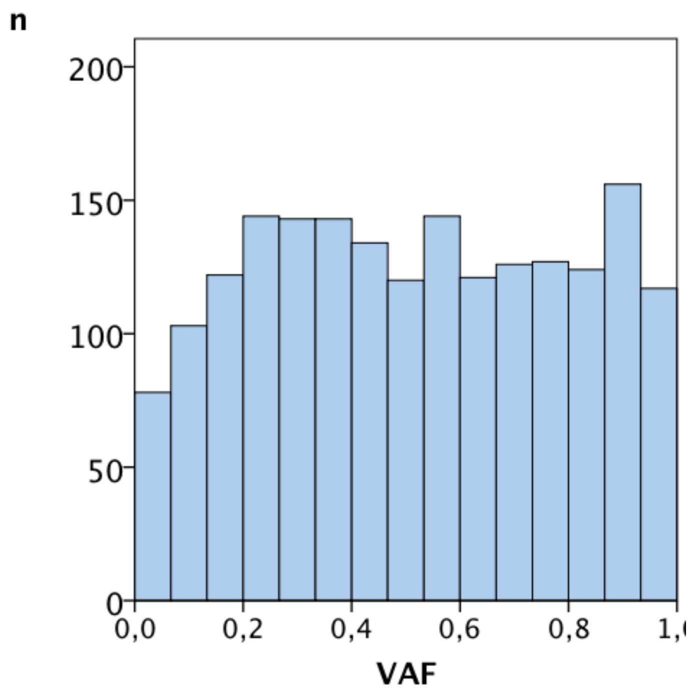
What the model does

Starting and ending fluctuations: A_s (and A_e), b_s (and b_e)



How the model fits the datas

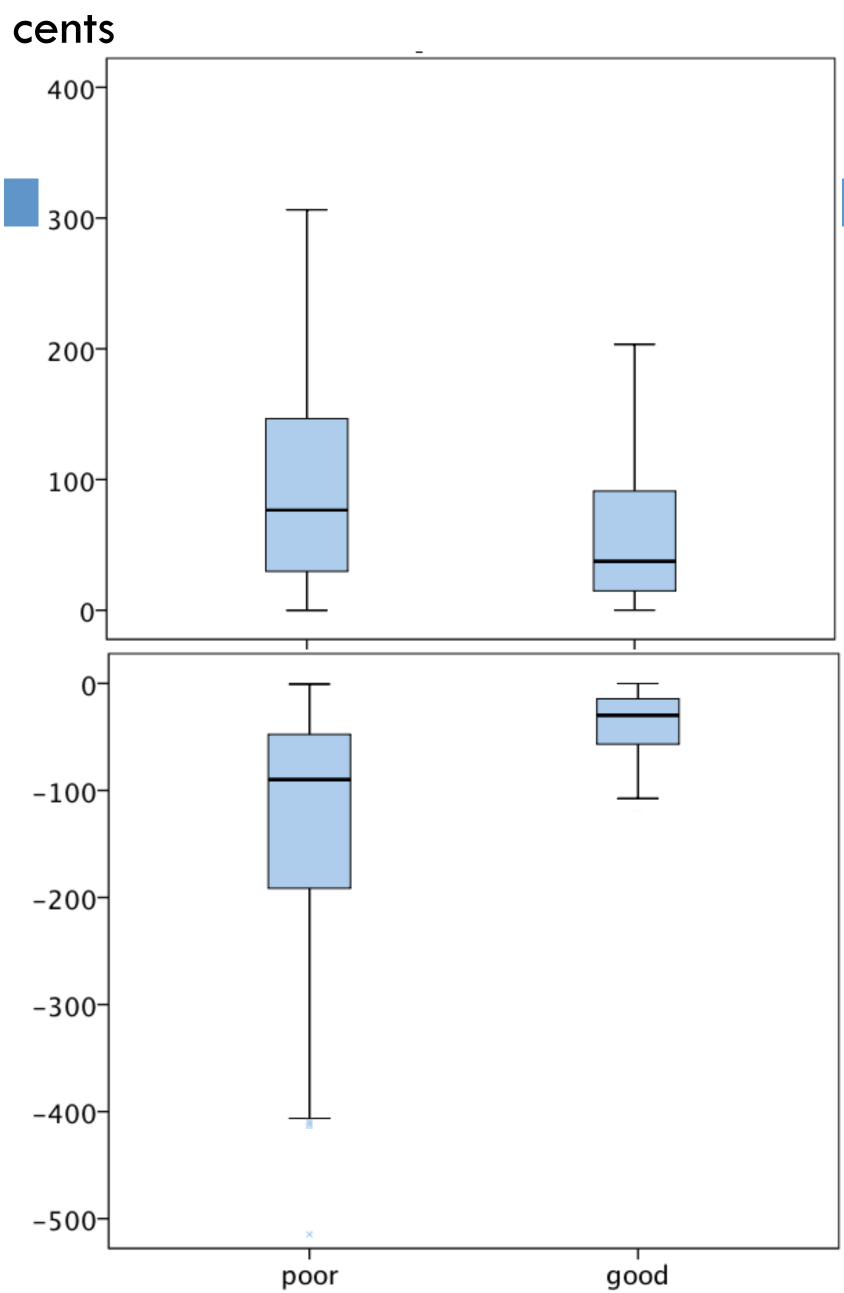
- Database
  - Pfordresher & Mantell (2014)
  - 12 "poor" and 17 "good" singers
  - Imitation of accurate singers
  - Melodies of 4 notes
  - 1902 tones to analyse



- Distribution (Shapiro-Wilk $p<.001$)

- Not different depending on the quality of the singer
  - $t(1459) = .473; p = .637$

Comparison poor/good singers for **pitch deviation**

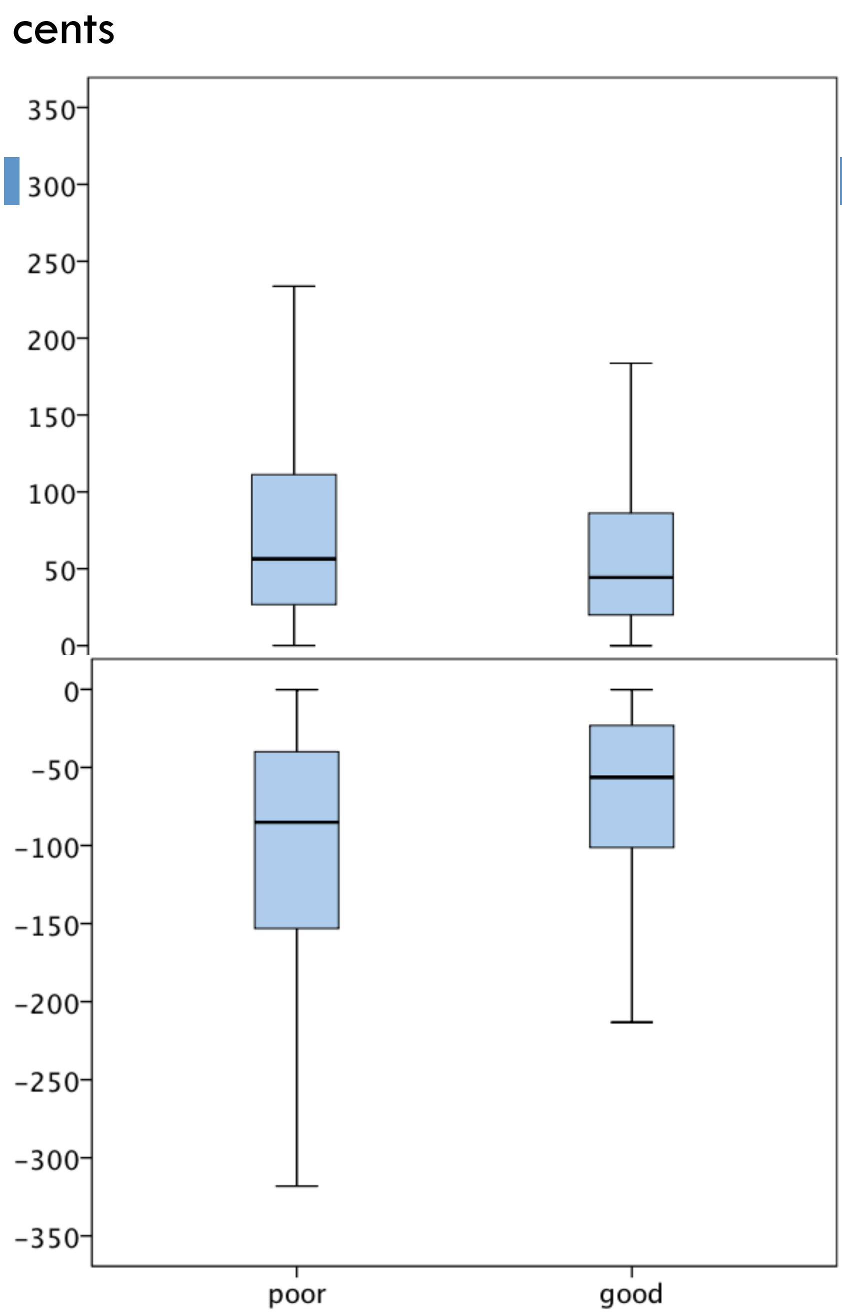


	Poor M (SE)	Good M (SE)	Dif
Above pitch	143.74 (13.68)	76.21 (5.45)	$p < .001$
Under pitch	-143.13 (7.15)	-47.75 (2.58)	$p < .001$

Comparison poor/good singers for b_s, b_e, f_s, f_e

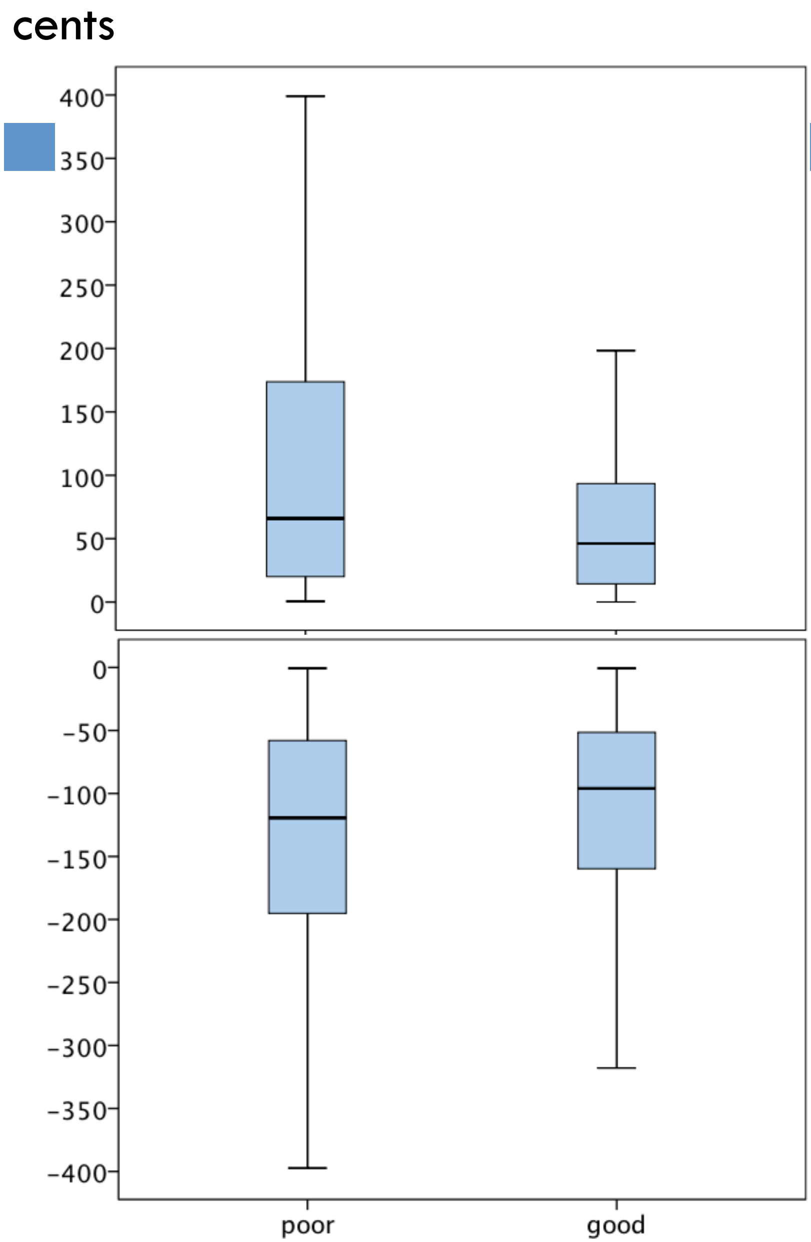
	Poor M (SE)	Good M (SE)	Difference
b	5.03 (.64)	6.02 (.57)	ns
b2	5.55 (.41)	5.16 (.37)	*p* = .003
f	1.11 (.32)	.68 (.30)	ns
f2	-.41 (.19)	-.35 (.11)	ns

Comparison poor/good singers for **As**



	Poor M (SE)	Good M (SE)	Dif
A above	86.41 (5.40)	60.53 (2.55)	$p < .001$
A under	-113.90 (6.01)	-76.11 (3.66)	$p < .001$

Comparison poor/good singers for **Ae**



	Poor M (SE)	Good M (SE)	Dif
A2 above	113.81 (10.38)	77.04 (8.39)	$p < .01$
A2 under	-148.96 (5.93)	-115.86 (3.34)	$p < .001$

Methods

- Creation of melodies
  - Pitch deviations on the 3rd note
  - Different sizes of As and Ae
  - Different combinations of As and Ae
- Pairwise comparison
  - Ranking: 1 point if “more in tune”, 0 point for the other, 0.5 point if similar
- Questions
  - Effect of the direction of the attack/ending ?
  - Effect of the size of the attack/ending ?

➔ **Pitch accuracy perception of natural voices**

Conclusions

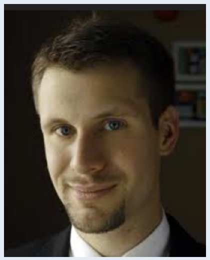
Within the tones

- Acoustical description of vocal tones
  - Successful modelisation
  - Beginning and end vary according to the "quality" of the singer
- Pitch accuracy perception
  - Coming soon ☺

Conclusions

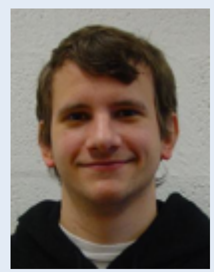
- Is Marilyn in tune?
- Perception of pitch accuracy
  - Perception of musical errors
  - Between the tones: pitch categories
  - Within the tones: pitch fluctuation
- Definition/representation of singing accuracy
- … and speaking accuracy?

How do we perceive vocal pitch accuracy during singing?







Conservatoires Royaux de Belgique
Centre Henri Pousseur
Ellen Blanckaert
Virginie Roig-Sanchis

March 3rd
2014

How do we perceive vocal pitch accuracy during singing?

Thank you!

March 3rd
2014

References

- Berkowska, M., & Dalla Bella, S. (2009). Reducing linguistic information enhances singing proficiency in occasional singers. Annals of the New York Academy of Sciences, 1169, 108-111.
- Castellengo, M. (1994). La perception auditive des sons musicaux. In A. Zenatti (Ed.), Psychologie de la musique (pp.55-86). Paris: Presses Universitaires de France.
- d'Alessandro C., Castellengo M. (1994), The pitch of short-duration vibrato tones. JASA., 95(3)
- Dalla Bella, S., & Berkowska, M. (2009). Singing Proficiency in the Majority. *Annals of the New York Academy of Sciences, 1169*(1), 99-107.
- Dalla Bella, S., Giguère, J. -F., & Peretz, I. (2007). Singing proficiency in the general population. *The Journal of the Acoustical Society of America, 121*(2), 1182-1189.
- Dalla Bella, S., Giguère, J.-F., & Peretz, I. (2009). Singing in congenital amusia. The Journal of the Acoustical Society of America, 126(1), 414.
- Dowling, W. J, & Fujitani, D. S. (1970). Contour, interval, and pitch recognition in memory for melodies. *Journal of the Acoustical Society of America, 49*, 524-531.
- Edworthy. J. (1985). Interval and contour in melody processing. *Music Perception, 2*, 375-388.

References

- Ferland, M. B., & Mendelson, M. J. (1989). Infants' categorization of melodic contour. *Infant Behaviour Development, 12*, 341-355.
- Gooding, L., & Standley, J. M. (2011). Musical development and learning characteristics of students: A compilation of key points from the research literature organized by age. *National Association for Music Education, 30*(1), 32-45.
- Hannon, E. E., & Trainor, L. J. (2007). Music acquisition : effects of enculturation and formal training on development. *Trends in Cognitive Sciences, 11*(11), 466-472.
- Hutchins, S., & Peretz, I. (2012). A frog in your throat or in your ear? Searching for the causes of poor singing. *Journal of Experimental Psychology: General, 141*, 76–97.
- Hutchins, S., Roquet, C., & Peretz, I. (2012). The Vocal Generosity Effect: How Bad Can Your Singing Be? Music Perception, 30(2), 147-159.
- Kinney, D. W. (2009). Internal Consistency of Performance Evaluations as a Function of Music Expertise and Excerpt Familiarity. Journal of Research in Music Education, 56(4), 322-337.
- Large, E. W., Fink, P., & Kelso, J. A. S. (2002). Tracking simple and complex sequences. Psychological Research, 66, 3-17.
- Larrouy-Maestri, P., & Morsomme, D. (in press). Criteria and tools for objectively analysing the vocal accuracy of a popular song. *Logopedics Phoniatrics Vocology*.

References

- Larrouy-Maestri, P., Lévêque, Y., Schön, D., Giovanni, A., & Morsomme, D. (2013) The evaluation of singing voice accuracy: a comparison between subjective and objective methods. *Journal of Voice*. 27(2), 259.e251-e255.
- Larrouy-Maestri, P., Magis, D., & Morsomme, D. (2014). Effects of melody and technique on acoustical and musical features of Western operatic singing voices. *Journal of Voice*.
- Larrouy-Maestri, P., Magis, D., & Morsomme, D. (in press a). The effect of melody and technique on the singing voice accuracy of trained singers. *Logopedics Phoniatrics Vocology*.
- Larrouy-Maestri, P., Magis, D., & Morsomme, D. (in press b). The evaluation of vocal accuracy: The case of operatic singing voices. *Music perception*.
- Peretz, I., & Coltheart, M. (2003). Modularity of music processing. Nature Neuroscience, 6(7), 688-691.
- Plantinga, J., & Trainor, L. (2005). Memory for melody: infants use a relative pitch code. *Cognition, 98*(1), 1-11.
- Pfordresher, P. Q., & Brown, S. (2007). Poor-pitch singing in the absence of "tone deafness". *Music Perception, 25*(2), 95-115.
- Pfordresher, P. Q., & Brown, S. (2009). Enhanced production and perception of musical pitch in tone language speakers. Attention, Perception & Psychophysics, 71(6), 1385-1398.

References

- Pfordresher, P. Q., Brown, S., Meier, K. M., Belyk, M., & Liotti, M. (2010). Imprecise singing is widespread. *The Journal of the Acoustical Society of America, 128*(4), 2182-2190.

- Pfordresher, P. Q., Brown, S., Meier, K. M., Belyk, M., & Liotti, M. (2010). Imprecise singing is widespread. *The Journal of the Acoustical Society of America, 128*(4), 2182-2190.

- Pfordresher, P. Q., & Mantell, J. T. (2014). Singing with yourself: Evidence for an inverse modeling account of poor-pitch singing.
- Stalinski, S. M., Schellenberg, E. G., & Trehub, S. E. (2008). Developmental changes in the perception of pitch contour. Distinguishing up from down. *Journal of the Acoustical Society of America, 124*, 1759-1763.
- Sundberg, J. (2013). Perception of Singing. In D. Deutsch (Ed.), *The psychology of music* (pp. 69-105). San Diego, CA: Academic Press.
- Trainor, L. J., & Trehub, S. E. (1992). A comparison of infants' and adults' sensitivity to Western musical structure. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 394–402.
- van Besouw, R. M. V., Brereton, J. S., & Howard, D. M. (2008). Range of tuning for tones with and without vibrato. Music Perception, 26(2), 145-155.
- Warrier, C. M., & Zatorre, R. J. (2002). Influence of tonal context and timbral variation on perception of pitch. Perception & Psychophysics, 64(2), 198-207.