How do we perceive vocal pitch accuracy during singing?

Pauline Larrouy-Maestri & Peter Q Pfordresher
In tune?
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
- **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

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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

March 3rd 2014

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Computer assisted method

Manual segmentation
AudioSculpt (Ircam)

F0 information
AudioSculpt and OpenMusic (Ircam)

Quantification of errors
Excel (Microsoft)

<table>
<thead>
<tr>
<th></th>
<th>Experts</th>
<th>Non experts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>8 women</td>
<td>8 women</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>$M = 29.89; SD = 14.47$</td>
<td>$M = 33.06 ; SD = 9.57$</td>
</tr>
<tr>
<td><strong>Expertise</strong></td>
<td>5 professional musicians 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>professional singers 4 music</td>
<td></td>
</tr>
<tr>
<td></td>
<td>students 4 speech therapists</td>
<td></td>
</tr>
<tr>
<td><strong>Musical or vocal practice</strong></td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td><strong>Audiometry</strong></td>
<td></td>
<td>OK</td>
</tr>
<tr>
<td><strong>MBEA (Peretz et al., 2003)</strong></td>
<td>____</td>
<td>OK</td>
</tr>
<tr>
<td><strong>Production task « Happy Birthday »</strong></td>
<td>____</td>
<td>OK</td>
</tr>
</tbody>
</table>
### Results

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Non experts</th>
<th>Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>$F(3,165) = 104.44; \ p &lt; .01$</td>
<td>$F(3,165) = 231.51; \ p &lt; .01$</td>
</tr>
<tr>
<td>% variance</td>
<td>66%</td>
<td>81%</td>
</tr>
<tr>
<td><strong>Criteria</strong></td>
<td>Interval deviation</td>
<td>Interval deviation</td>
</tr>
<tr>
<td></td>
<td>Tonality modulations</td>
<td></td>
</tr>
</tbody>
</table>

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
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

Which threshold in a melodic context?
Effect of the direction of the error?
Two melodies

Familiarity?

- Online questionnaire
- 399 participants from 13 to 70 years old (M = 29.81)
- t(398) = 20.92, p < .001
Material
Participants and procedure

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

Method of limits
van Besouw et al., 2008
## Comparison test-retest

<table>
<thead>
<tr>
<th></th>
<th>Test M(SE)</th>
<th>Retest M(SE)</th>
<th>R Pearson</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Familiar melody</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enlargement</td>
<td>15.43 (1.24)</td>
<td>17.33 (1.12)</td>
<td>.69**</td>
<td>T(29) = 2.04, ns</td>
</tr>
<tr>
<td>Compression</td>
<td>26.07 (1.98)</td>
<td>23.40 (1.66)</td>
<td>.82**</td>
<td>T(29) = 2.36*</td>
</tr>
<tr>
<td>Tolerance</td>
<td>41.50 (2.50)</td>
<td>40.73 (1.89)</td>
<td>.82**</td>
<td>T(29) = 0.54, ns</td>
</tr>
<tr>
<td><strong>Non familiar melody</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enlargement</td>
<td>17.20 (1.33)</td>
<td>17.80 (1.12)</td>
<td>.68**</td>
<td>T(29) = 0.60, ns</td>
</tr>
<tr>
<td>Compression</td>
<td>25.30 (1.84)</td>
<td>22.23 (1.46)</td>
<td>.84**</td>
<td>T(29) = 3.03**</td>
</tr>
<tr>
<td>Tolerance</td>
<td>42.50 (2.05)</td>
<td>40.03 (1.95)</td>
<td>.80**</td>
<td>T(29) = 1.93, ns</td>
</tr>
</tbody>
</table>

→ **Good intra-judges reliability**

→ **Learning effect?**
Results

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

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<thead>
<tr>
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<th>Familiar</th>
<th>Non Familiar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>66.44</td>
<td>71.03</td>
</tr>
<tr>
<td>Retest</td>
<td>72.64</td>
<td>71.72</td>
</tr>
</tbody>
</table>

- Good inter-judges reliability
- Learning effect?
Results

- **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**
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
- 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 asymptote

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

$Pitch_t = Y_{st} + Y_{et} + asym$

Beginning perturbation

Approach to asymptote

Oscillation around target (overshoot)

Approach is down ($= 0$) Or up ($= \pi$)

Similar to starting fluctuations, except
- Time values mirror reversed
- New and adjusted parameters

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The only fitted parameters are
- Rate of approach: $b_s, b_e$
- Oscillation around target: $f_s, f_e$

Others come from data
- $\text{ asym}$: from middle portion of tone (median)
- $A$ values from difference of beginning to $\text{ asym}$
- $A_e$ values from difference of end to $\text{ asym}$
- $\theta$ is effectively a ‘toggle’
What the model does

Starting fluctuations: magnitude (A) and rate of approach (b)
What the model does

Oscillation around approach (f = 10)

A = 100 b = 10c

A = 100 b = 5c

A = 100 b = 1c

A = 50 b = 10c

A = 50 b = 5c

A = 50 b = 1c

A = 10 b = 10c

A = 10 b = 5c

A = 10 b = 1c
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

<table>
<thead>
<tr>
<th></th>
<th>Poor M (SE)</th>
<th>Good M (SE)</th>
<th>Dif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above pitch</td>
<td>143.74 (13.68)</td>
<td>76.21 (5.45)</td>
<td>$p &lt; .001$</td>
</tr>
<tr>
<td>Under pitch</td>
<td>-143.13 (7.15)</td>
<td>-47.75 (2.58)</td>
<td>$p &lt; .001$</td>
</tr>
</tbody>
</table>
Comparison poor/good singers for $b_s$, $b_e$, $f_s$, $f_e$

<table>
<thead>
<tr>
<th></th>
<th>Poor M (SE)</th>
<th>Good M (SE)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>5.03 (.64)</td>
<td>6.02 (.57)</td>
<td>ns</td>
</tr>
<tr>
<td>b2</td>
<td>5.55 (.41)</td>
<td>5.16 (.37)</td>
<td>$p = .003$</td>
</tr>
<tr>
<td>f</td>
<td>1.11 (.32)</td>
<td>.68 (.30)</td>
<td>ns</td>
</tr>
<tr>
<td>f2</td>
<td>-.41 (.19)</td>
<td>-.35 (.11)</td>
<td>ns</td>
</tr>
</tbody>
</table>
Comparison poor/good singers for As

<table>
<thead>
<tr>
<th></th>
<th>Poor M (SE)</th>
<th>Good M (SE)</th>
<th>Dif</th>
</tr>
</thead>
<tbody>
<tr>
<td>A above</td>
<td>86.41 (5.40)</td>
<td>60.53 (2.55)</td>
<td>$p &lt; .001$</td>
</tr>
<tr>
<td>A under</td>
<td>-113.90 (6.01)</td>
<td>-76.11 (3.66)</td>
<td>$p &lt; .001$</td>
</tr>
</tbody>
</table>
Comparison poor/good singers for Ae

<table>
<thead>
<tr>
<th></th>
<th>Poor</th>
<th>Good</th>
<th>Dif</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
<td></td>
</tr>
<tr>
<td>A2 above</td>
<td>113.81 (10.38)</td>
<td>77.04 (8.39)</td>
<td>p &lt; .01</td>
</tr>
<tr>
<td>A2 under</td>
<td>-148.96 (5.93)</td>
<td>-115.86 (3.34)</td>
<td>p &lt; .001</td>
</tr>
</tbody>
</table>

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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

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How do we perceive vocal pitch accuracy during singing?

Thank you!

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2014


d'Alessandro C., Castellengo M. (1994), The pitch of short-duration vibrato tones. JASA., 95(3)


References


References


References