SSC 0158: The Science of Talking

Speaking and singing

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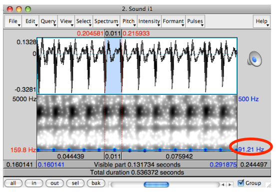
Overview

- Speaking vs. singing
- Vocal qualities in professional singing:
  - Vibrato
  - The singer's formant
- Musical deficits
  - Congenital amusia: music perception (and production)
  - Poor-pitch singing: music production
- Speech/song imitation lab

Some Notes on Fundamental Frequency (F0)

- **Fundamental Frequency (F0)**: the rate at which the vocal folds open and close during a voiced sound, in cycles / second or Hertz (Hz).
- In ordinary conversation, for European languages:
  - **Men** have an average F0 of **120** Hz, with a range of 50-250 Hz
  - **Women** have an average F0 of **220** Hz, with a range of 120-480 Hz
  - **Children** have an average F0 of **330** Hz
- Term:
  - Acoustic: Fundamental Frequency (F0)
  - Perceptual: Pitch
  - Linguistic: Tone
  - Music: Note



The blue line: **pitch track**

Period (T): the length of time taken by one cycle

F0 = 1/period = 1/T

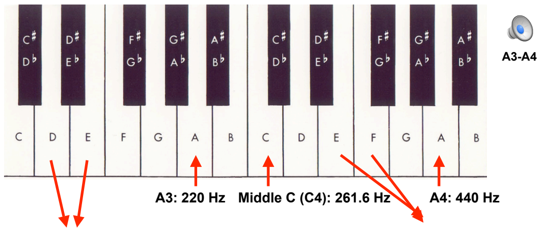
= 1/0.011

= 90.91 Hz

https://webdisk.ucalgary.ca/~swinters/public_html/ling441/index.html

Some Notes on Music

- In Western music, there are **twelve notes** in each octave
  - **7** "natural" notes: C, D, E, F, G, A, B (white keys)
  - **5** "sharp/flat" notes (black keys)



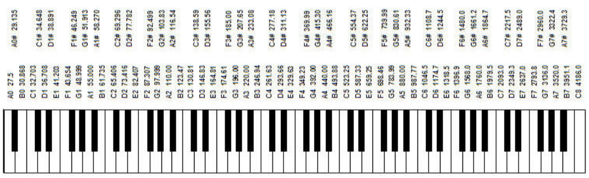
D and E are **2 semitones** apart; the note between them can be called **D sharp** or **E flat**

E and F are **1 semitone** apart

https://webdisk.ucalgary.ca/~swinters/public_html/ling441/index.html

Some Notes on Music

- The lowest note on a piano is "**A0**", which has a fundamental frequency of **27.5 Hz**.
- The frequencies of the rest of the notes are multiples of 27.5 Hz.
- $F_n = 27.5 * 2^{(n/12)}$
  - where n = number of note above A0
  - There are 87 notes above A0 in all



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Speaking vs. singing

Speaking

- "**Talk** is cheap." -- English proverb
- **Absence** of *vibrato* and *the singer's formant* (Brown et al., 2000)
- "Tight control of voice F0 is **unnecessary**" (Natke et al., 2003)
- **Linguistic melody**: "a group of tones that work together to get a job done", "in the service of quotidian linguistic functions" (Patel, 2008: 184)

Singing

- "**Music** is the universal language of mankind." -- Henry Wadsworth Longfellow (1807-1882)
- **Presence** of *vibrato* and *the singer's formant*
- "Tight control of voice F0 seems **preferable**"
- **Musical melody**: "a group of tones in love with each other" (Simon Shaheen, quoted in Hast et al., 1999)

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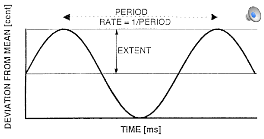
Vibrato

- Vibrato is a musical effect consisting of a regular pulsating change of pitch.
- Parameters:
  - **Rate**: # of undulations per second (5 to 7 Hz)
  - **Extent**: How far phonation frequency departs up and down from its average during a vibrato cycle (narrower than ± 1 semitone)
  - **Regularity**: How similar the frequency excursions are to one another
  - **Waveform**: Similar to a sine wave



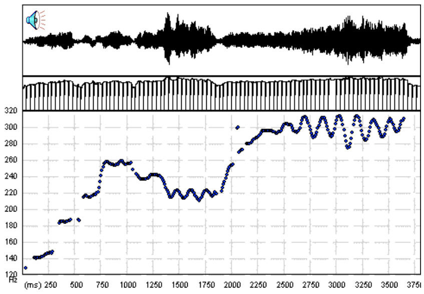
Sundberg, J. 1995. Acoustic and psychoacoustic aspects of vocal vibrato.

Functions:

1. Vibrato gives the singer access to fine tuning as a means of musical expression.
2. Vibrato makes the singer's voice easier to discern against the background of a loud orchestral accompaniment.

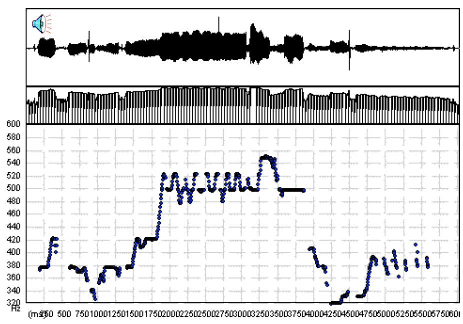
http://en.wikipedia.org/wiki/Vibrato

Dietrich Fischer-Dieskau: The second greatest singer of the 20th century (after Jussi Björling)



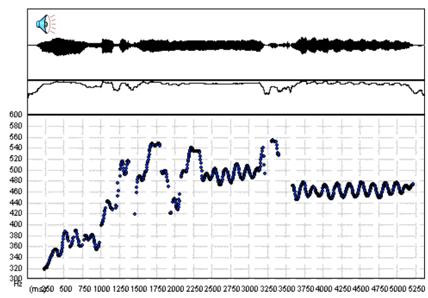
http://www.linguistics.ucla.edu/people/keating/2008_lab_seminar.ppt

Joan Baez: An American folk singer, songwriter and activist



http://www.linguistics.ucla.edu/people/keating/2008_lab_seminar.ppt

Kelly Clarkson: An American singer-songwriter and actress



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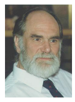
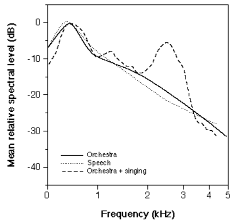
The singer's formant

- Discovered by Johan Sundberg (1970), a Swedish phonetician.
- Classically trained vocalists (e.g., Swedish operatic tenor Jussi Björling) typically have a high frequency resonance around 3000 Hz when they sing.


Johan Sundberg

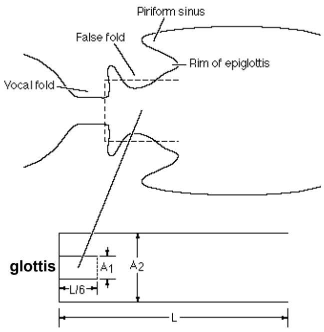

Jussi Björling



- This enables them to be heard over the din of the orchestra.
- Not an *additional* formant, but a clustering of F3, F4, F5; when they are close together in frequency their strengths are mutually enhanced and they give one broad strong spectral peak.

http://www.ncvs.org/ncvs/tutorials/voiceprod/tutorial/singer.html

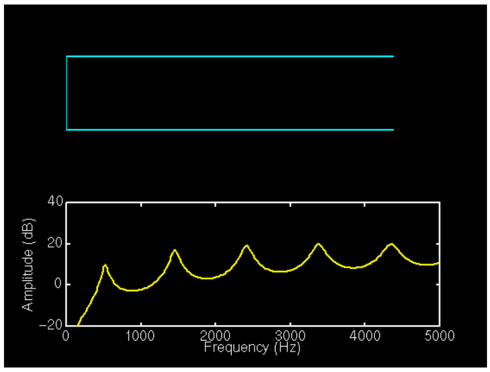
How do they do it?



- Evidently, singers form a short (~3 cm), narrow tube near their glottis by making a constriction with their epiglottis
- This short tube resonates at around 3000 Hz

http://www.ncvs.org/ncvs/tutorials/voiceprod/tutorial/singer.html

Singer's formant demo



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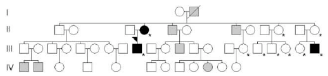
Congenital amusia

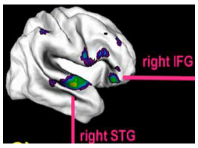
- Severe problems with music perception and production (Ayotte et al., 2002[1]; Dalla Bella & Peretz, 2003[2]; Dalla Bella et al., 2009[3]), e.g.,
  - *Carrying a tune*[1,3]
  - *Dancing or tapping along with music*[1,2]
  - *Detecting anomalous pitches in melodies*[1]
  - *Judging dissonance in musical excerpts*[1]
  - *Recognizing or memorizing melodies without lyrics*[1]

Congenital amusia

- Strong genetic component (Drayna et al., 2001; Peretz, et al., 2007)



- Amusic brains are structurally different from neurotypical brains in subtle ways (Hyde et al., 2006, 2007; Mandell et al., 2007; Loui et al., 2009)



Reduced white matter in right IFG (inferior frontal gyrus)

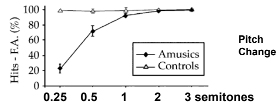
Thicker cortex in right IFG and right STG (superior temporal gyrus -- secondary auditory area)

- Prevalence ~4% (Kalmus & Fry, 1980)

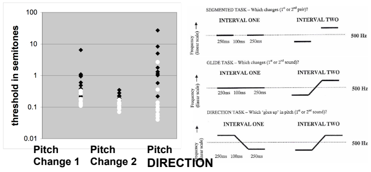
There was an old fellow of Sheen
whose musical sense was not keen.
He said: "It is odd,
I can never tell 'God
save the weasel' from 'Pop goes the Queen'!"

Core deficit?

- Fine-grained pitch discrimination (Hyde & Peretz, 2004; Peretz, 2008)



- Pitch pattern/direction perception (Foxton et al., 2004; Griffiths, 2008; Stewart, 2008)



- "Melodic Contour Deafness Hypothesis" (Patel, 2008: 233)


Ani Patel


Isabelle Peretz


Tim Griffiths

The Montreal Battery of Evaluation of Amusia (MBEA)

http://www.brams.umontreal.ca/plab/research/Stimuli/mbea_variety/mbea_variety_stimuli.html

Standard

Scale

Contour

Interval

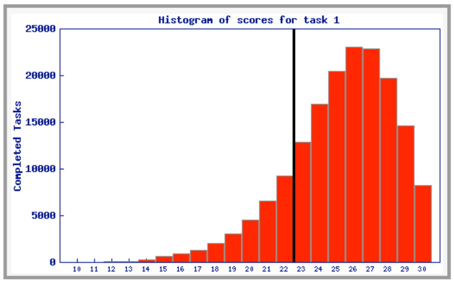
Rhythm

Metre

Peretz I, Champod S, Hyde K. Varieties of musical disorders: the Montreal Battery of Evaluation of Amusia. Ann N Y Acad Sci 2003; 999: 58-75.

Online musical listening test

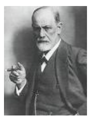
(http://www.delosis.com/listening/home.html)



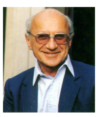
MBEA Scale subtest, taken ~ 160,000 times

Why is it interesting?

- In everyday life, the disorder seems specific to music
- Are there genes that *selectively* influence everyday musical abilities?
  - Relevant for debates over the evolution of music


Sigmund Freud

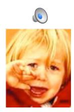
- How specific is the disorder to music, really?
  - Relevant to understanding underlying mechanisms


Milton Friedman

Patel, A. D. (2008). Music, Language, and the Brain. NY: Oxford University Press.

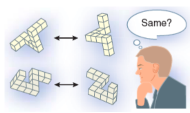
Growing evidence for non-domain specificity

- Deficits revealed in the lab:
  - *Judging emotional prosody*
    - Thompson (2007)

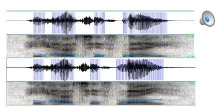

Fear


Irritation

  - *Spatial processing / mental rotation?*
    - Douglas & Bilkey (2007): Yes
    - Tillmann et al. (2010): No



  - *Speech intonation processing*
    - Impaired statement-question identification/discrimination/imitation (Liu et al., 2010)



Speaking in congenital amusia

- **The Story of Arthur the Rat:** A15: C6:

  "There was a kindly horse named Nelly, a cow,

  a calf, and a garden with an elm tree."

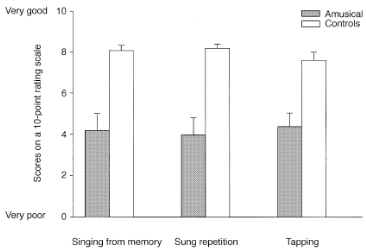
- **Three vowels:** A15: C6:
  - EE (*as in 'bee'*)
  - AH (*'bar'*)
  - OO (*'boo'*)

Normal:
Pitch range
Pitch regularity
Voice quality
Contact phase regularity of vocal fold vibration

Liu et al. (2010)

Singing in congenital amusia

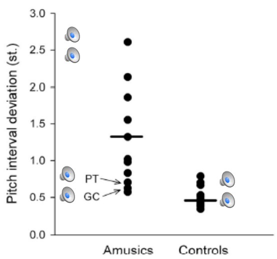
- Impaired singing and tapping
- Singing inaccuracy: More on pitch than on rhythm
- One amusic performed normally on all three tasks



Ayotte et al. (2002)

Singing in congenital amusia

- 9/11 amusics were poor singers, mostly on the **pitch** dimension. 2 amusics sang proficiently (separability between perception and production).
- > half of the amusics sang **in-time**.
- Poor singers made numerous pitch **interval** and **contour** errors, produced **pitch intervals** largely **deviating** from the score, and **lacked pitch stability**.
- > half of the amusics failed to sing more than a few notes when singing the same song on **/la/**.



Dalla Bella et al. (2009)

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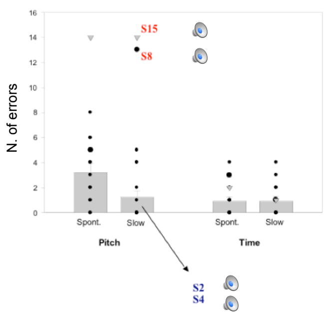
Singing proficiency in the general population

- Occasional singers can sing as well as professional singers **at a slow tempo**, with pitch interval deviation ~ 0.3 semitones.
- 2 individuals cannot sing proficiently.
  - **Out-of-tune,** with pitch interval deviation ~ 1 semitone
  - **In-time**
  - **No perceptual deficit**.



Dalla Bella et al. (2007)

Poor-pitch singing

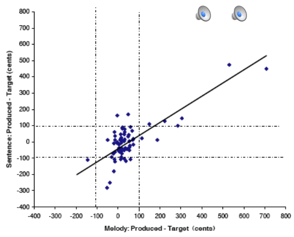
- Poor-pitch singing ***in the absence of*** pitch perception deficits (Dalla Bella et al., 2007; Pfordresher & Brown, 2007).
  - "In tune": how close to target is close enough (about **0.20-0.25 semitones** by expert listeners) (Vurma & Ross, 2003)
  - "Poor-pitch singing": failure to match pitches or pitch intervals within **1 semitone** of the target, by **transposing pitches (mistuning)** and/or **compressing pitch intervals**
- **Prevalence** 10-15%
- **Faulty sensorimotor integration** (mismapping of pitch onto action)

Peter Pfordresher

Simone Dalla Bella

The relationship between speaking and singing in speech/song imitation

- Absolute pitch was imitated more accurately in **song** than in **speech** (Mantell & Pfordresher, 2010).
- **Correlation**: Individuals who cannot imitate song well tend also to imitate speech inaccurately (Pfordresher & Mantell, 2009).
- **Q: Can we replicate the results in our speech/song imitation lab?**



100 cents = 1 semitone
(Pfordresher & Mantell, 2009)

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Speech/song imitation lab

- **Model stimuli**: from Dr David Gerhard's speech/song corpus (http://www2.cs.uregina.ca/~gerhard/)
  - '(row, row, row your boat,) gently down the stream' (a familiar song)
  - '(O Canada,) our home and native land' (an unfamiliar song, hopefully)
- **Measurement**: absolute pitch difference (averaged across the syllables in each sequence) between the model production and your imitation
- **Research questions**:
  - Is song imitated better than speech?
  - Is the familiar song imitated better than the unfamiliar one?
  - Do native speakers of English imitate speech better than foreign speakers?
  - Do women have better imitation skills than men?
  - Do people tend to have similar (in)accuracy in imitating speech and song?

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