

Auditory Illusions Phy103 Physics of Music



### J. S. Bach's canon per tonus

A very famous example of an endlessly rising melody is the *canon per tonus* from Johann Sebastian Bach's Musical Offering. The melody rises two half-tones each time the canon is repeated (this should illustrate the rising glory of Frederick the Great to whom the Musical Offering was dedicated). The canon starts in C minor. After the first run it ends in D minor, so the second turn begins two halftones higher than the first one. When the canon is repeated further, it begins in: c1, d1, e1, f#1, g#1, b*b*1, c2, d2.

### Canon circularis per tonos (Bach) A musical offering



### Descending Pitch Illusion



http://asa.aip.org/demo27.html



### Falling bells

• Pitch is actually rising even though it sounds like it is falling

From: http://listverse.com/2008/02/29/top-10incredible-sound-illusions/





- Each tone contains separations 7/6 of an octave with an envelope that is fixed
- Each tone is shifted by 100 center or 1 semitone



### A Melody of Silences

http://www.kyushu-id.ac.jp/~ynhome/ENG/Demo/illusions.html

#### c2000 Yoshitaka Nakajima





### Reflection as a compositional theme

- Bartok "Subject and Reflection", Mikrokosmos, vol 6, #141 played by Jeno Jando
- Can your ear pick out the reflective tonal symmetry without seeing the music?
- Two melodies played one goes up while the other goes down and vice versa

### Now with the music



### Now with the spectrum?



- Is the reflective tonal symmetry obvious in the spectrum?
- Compare how easy it is to SEE this pattern compared to how easy it is to HEAR this pattern

## Earthquakes from somewhere in Ethiopia – Cindy Ebinger

BOVE

reversed

- Original file sampled to 50Hz
- We multiplied by 400 to 20KHz
- 2 hours of data reduced to 18s



### Can we pick out time reversal symmetry (tune followed by itself played in reverse order)?

Without the music Anton Webern, Opus 27





Reflection in time -- now with the music Axis of symmetry is a time

Example from Larry Solomon) Anton Webern, Opus 27

### Sensory Integration Illusion

- What you see affects what you hear
- McGurk effect

http://www.youtube.com/watch?v=aFPtc8BVdJk

• Music dubbing

### Gap Transfer illusion



- A bounce is often perceived in the gliding tones
- http://www.kyushuid.ac.jp/~ynhome/ ENG/Demo/2nd/ 01.html

### More on Gap-Transfer Illusion



• Often perceived the same

### Split off effect

• The listener typically perceives one long tone, which rises and then falls, and a short tone in the middle.



### More on the split off effect



### More on split off effect





### Streaming

- When do two alternating pitches sound like one galloping sound?
  - ASA demo 19
- Yodeling apparent motion in music
  Cook demo 33



- From: <u>http://listverse.com/2008/02/29/top-10-incredible-sound-illusions/</u>
- Christian Sinding's Frühlingsrauschen ("Rustle of Spring") original recording: www.classicalmidi.co.uk / Slow recording courtesy of Karle-Philip Zamor)

Fast rhythm even in presence of timbre variations can lead to hearing groups of sounds as single sounds "perceptual groupings"

# King Crimson Discipline



### Overlapping piano tones

- forward
- backward
  overlaps aren't
  really heard



### Illusory Continuity

 Speech is heard and understood despite noise interruptions



### Temporal Induction of Speech



From New Scientist. Music special: Five great auditory illusions 24 February 2008 by Michael Marshall

## Pitch depends on partial frequencies

- Butler example 3.5b
- Second of each pair has partials 10% sharp.
  Perceived pitch change depends on frequency

### Timbre depends on frequency

- First tone has partials 1,2,3,4,5
- Second tone has partials 1,3,5,7,9
- Difference in timbre depends on frequency of fundamental

• Butler example 3.5a

### A Discontinuous Change in Time Perception Caused by Time-Shrinking

• When the difference between the first and the second duration is up to about 100 ms (the sixth pattern), 'timeshrinking', i.e., the second duration is under-estimated

(a) First Series				(b) Second Series				
	[m s]	/tone burs	t					
1	160	160	1		160		160	
2	150	170	2		170		150	
3	140	180	3		180		140	
4	130	190	4		190		130	
5	120	200	5		200		120	
6	110	210	6		210		110	
7	100	220	7		220		100	
8	90	230	8		230		90	
9	80	240	9		240		80	
10	70	250	10		250		70	
11	60	260	11	L	260		60	





### Timing and music

**()**=

**()**=

Scott Joplin's The Peacherine

- MIDI from http://www.geocities.com/ BourbonStreet/2783/sjmidi.htm
- Played by Dick Hyman

Joplin sounds pretty good in MIDI --- it was played on piano rolls

### Quickening Beat

Tempo appears to be quickening





From: http://listverse.com/2008/02/29/top-10-incredible-sound-illusions/



### Combination tones!

- Listening example 4.5 Butler.
- Only 440 and 660 Hz played, but sometimes can hear a 220 Hz signal (difference) in addition to the other two.
- Lower tone is manufactured by your ear/ brain

### Stereo Auditory illusions

 Here I have focused on illusions that don't involved stereo --- however Diana Deutsch has a series of very interesting stereo illusions. Alternating pitches between ears often perceived as continuous patterns

### Chromatic illusion



### Deutsch's Tritone paradox

- A tritone is two pitches  $\frac{1}{2}$  an octave apart (e.g. C to F#)
- One pair of tritones is followed by another.
- The listener is asked to judge whether the tones ascend or descend
- Musicians often disagree



### Tritone paradox



- Transposition often causes one listener to change his/her mind even though music when transposed is perceived as the same
- Most listeners have a preferred orientation for the pitch circle in perceived tritones--- a form of absolute pitch that every listener has
- Listeners from different cultures can disagree on their pitch orientation

### Zwicker Tone

- Noise with a gap. A tone can be heard following the noise.
- The gap should be about the size of the critical band.
- I tried this but could not get the illusion to work. Perhaps needs to be done in a quiet environment.

### Expectations

• The unresolved leading tone that ends one of the movements of Iphigenia in Brooklyn (PDQ). Looking for the clip!