# Music, Cognition, and Computerized Sound

AN INTRODUCTION TO

# Psychoacoustics

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# Appendix C: Sound Examples on CD

### Chapter 1

1. Beats: pairs of equal-amplitude sines at 400+500, 400+490, 400+480, 400+470, 400+460, 400+450, 400+440, 400+430, 400+420, 400+410
2. Risset's musical beats example
a. Basic 100 Hz tone of seven harmonics, with amplitudes $1/f$
b. Seven such tones with fundamentals 100, 100.1, 100.2, 100.3, 100.4, 100.5, and 100.6 Hz
c. Seven equal-amplitude sinusoids with frequencies 700.0, 700.7, 701.4, 702.1, 702.8, 703.5, 704.2 Hz. This is a synthesis of the seventh harmonics of example 2b.
3. 
a. High sines mask low: 500 Hz tone at 0 dB with lower tones at −40 dB, 300, 320, 340, 360, 380, 400, 420, 440, 460, 480 Hz
b. Low sines mask high: 500 Hz tone at 0 dB with higher tones at −40dB, 1700, 1580, 1460, 1340, 1220, 1100, 980, 860, 740, 620 Hz

### Chapter 2

No sound examples

### Chapter 3

- Size constancy audio examples are in chapter 20 sound examples.
4. Temporal inversion examples
a. Arpeggiated chord on the piano with three clearly defined tones
b. Same sound as above, but reversed. How many notes do you hear? Can you hear the order of note releases?
c. Brick tapped with a hammer (twice)
d. Same sound backward (twice)
e. Speech forward with reverb

g. Voice with lots of forward reverb
h. Voice with lots of backward reverb
5. Bregman perceptual completion examples
a. Sinusoid going up and down in pitch, with pauses at the top
b. Gaps in previous example are filled with noise. Now the sine wave sounds continuous, but is just obscured by the noise bursts
c. Musical example with gaps (Dan Trueman, Hardanger Fiddle)
d. Musical example with gaps filled by noise bursts
6. Common fate example. When separate frequency modulation functions are applied to the odd versus even harmonics of a tone, two sounds are heard. (After Steven McAdams.)
• More common fate examples are in chapter 20 sound examples.
• For examples of singing without vibrato, the listener is directed to recordings by the Bulgarian Women's Choir.

**Chapter 4**

7. Building a sawtooth by harmonics
a. top down
b. bottom up
• Equal loudness contour examples are in the sound examples of chapter 6.
8. Waveforms with 12 equal-amplitude sinusoids using cosine/Schroeder/random phase, at fundamental frequencies of 880, 440, 220, 110, 55, and 27.5 Hz
9. Phase vocoder examples: time stretched/pitch shifted speech

**Chapter 5**

10. Bright versus dull spectra
a. Human vowels "eee" and "ooo"
b. Trombone and french horn notes
11. Adding harmonic partials of equal amplitudes. We hear a strengthening of the pitch frequency with each additional harmonic. We also hear a high pitch associated with the small wiggles in the waveform
a. at 55 Hz
b. at 440 Hz
12. Tone bursts from figure 5.1
a. Four periods of 13.5, 27.5, 55, 110, 220, 440, 880, 1760, 3520 Hz
b. 10 periods of 13.5, 27.5, 55, 110, 220, 440, 880, 1760, 3520 Hz
c. 25 periods of 13.5, 27.5, 55, 110, 220, 440, 880, 1760, 3520 Hz



13. Wiggly waveforms from figure 5.3, tunes played near 55 and 440 Hz
a. 12 successive harmonics with amplitudes 1.2, 1.1, 1.0, . . .
b. 6 successive harmonics with amplitudes 1.2, 1.0, 0.8, . . .
c. Harmonics 7–12 with amplitudes .4, .8, 1.2, 1.2, .8, .4
14. Tone bursts from figure 5.4; 4000 Hz tone used in all examples
a. 300 bursts/second for waveform a
b. 300 bursts/second for waveform b
c. 300 bursts/second for waveform c
d. 400 bursts/second for waveform a
e. 400 bursts/second for waveform b
f. 400 bursts/second for waveform c
g. 160 bursts/second for waveform a
h. 160 bursts/second for waveform b
i. 160 bursts/second for waveform c
15. All versus odd harmonics. Tone with 12 successive harmonics followed by tone with 6 odd harmonics at frequencies 880, 440, 220, 110, 55, and 27.5 Hz.
• Shepard tone examples are included in chapter 10 sound examples.
• Risset tone sound examples are included in chapter 10 sound examples.

**Chapter 6**

16. Equal loudness examples
a. Equal amplitude sinusoids at 55, 82.5, 110, 165, 220, 330, 440, 660, 880, 1320, 1760, 2640, 3520, 5280 Hz. Listen to this series at a number of levels
b. Same sinusoids adjusted in amplitude to follow the equal loudness contour at 90 dB SPL, 50 sones loudness level.
17. Which is twice louder, 5 dB or 10 dB? Tone pair on 500 Hz, second tone 5 dB louder. Same tone pair, second tone 10 dB louder.
18. Complex sounds composed of partials. Which sounds louder?
a. A single sine wave at 1000 Hz
b. A tone of the same power, consisting of sine waves at 500, 1000, 1500, 2000, 2500, and 3000 Hz
c. A tone of the same power, consisting of sine waves at 500, 1100, 1773, 2173, 2717, and 3141 Hz

### Chapter 7

19. Waveforms from figure 7.1
  a. 12 equal-amplitude sinusoids
  b. 12 sinusoids, 3 dB/octave rolloff
  c. 12 sinusoids, 6 dB/octave rolloff
  d. 12 sinusoids, 9 dB/octave rolloff
  e. 12 sinusoids, 12 dB/octave rolloff
20. Holy tones 1–9, from figure 7.4
21. Violin without body, violin with body (Dan Trueman, violin)

### Chapter 8

22. The cocktail party effect
  a. Two speakers, one location
  b. Two speakers, two locations
23. Precedence effect
  a. Same voice on both speakers
  b. Same voice, phase inverted on both speakers
24. Sines plus noises in binaural (after Moore) (use headphones)
  a. Sines plus noise, in phase
  b. Sines in phase, plus noise out of phase
  c. Sine and noise, one ear only
  d. Sine one ear, noise in phase, both ears
25. Reverberation (Dan Trueman, violin)
  a. Music without reverberation
  b. Same music with reverberation
26. Binaural recording, jingling keys (use headphones)
  a. Left to right
  b. Center front to center above head
27. Gaussian pulse trains
  a. Average 33 pulses/second
  b. Average 67 pulses/second
  c. Average 125 pulses/second
  d. Average 250 pulses/second
  e. Average 500 pulses/second
  f. Average 1000 pulses/second
  g. Average 2000 pulses/second
  h. Average 4000 pulses/second

### Chapter 9

28. The source-filter model of the voice
  a. A single click of glottal closure
  b. Single clicks on different vowels
  c. A periodic glottal source
  d. c through "ahh" filter
  e. c through "eee" filter
  f. c through "ooo" filter
29. Spectral tilt as function of vocal effort
  a. Loud singing
  b. Soft singing
  c. a and b normalized to same power
30. Source/filter consonants
  a. Noise source
  b. Filtered "fff"
  c. Filtered "sss"
  d. Filtered "shh"
  e. Filtered "xxx"

### Chapter 10

31. Grouping by timbral similarity: trumpet tones alternating with a vocal tone and a steel drum sound
32. Segregation examples (after Bregman)
  a. High and low pitch played in succession; easy to follow as single line
  b. High-low-high pattern repeated ever faster until there are two streams of pitches
  c. Slow alternation between notes a minor second apart. Note that it is easy to think of the sound as a single line
  d. Same as c, but the interval is wider
  e. Same interval as c, but faster
  f. Same interval as d, but faster
  g. Same as c, even faster. Do you hear one or two lines?
  h. Same as d, even faster. Do you hear one or two lines?
33. Apparent motion in music: yodeling
34. Interleaved melodies
  a. Example from figure 10.4
  b. Same as a, increasing distance between melodies each time
  c. Separation of a by volume
  d. Separation of a by timbre

e. Two new melodies, increasing distance
f. Separation of e by volume
g. Separation of e by timbre
35. Warren loop
36. Wessel loops
a. Arpeggio with same timbre for all notes. Single perceived line arpeggiating upward
b. Increase in the timbral difference from a. Now it is easy to hear two lines arpeggiating downward.
37. Musical example of interleaved melodies
- Bach Violin Partita in D minor (Meesun Hong, violin)
- Shepard tones are in chapter 13 sound examples.

## Chapter 11

38. Formant shifts with head size and pitch
39. Vowel sounds associated with five vocal tract shapes, two of which are unreasonable
40. Normal, emphasized, and sinusoidal vowels
41. Examples of flanging
42. Singing with and without the singer's formant

## Chapter 12

43. Ambiguous speech sounds
a. goo, doo, boo
b. a played backward. Note how much easier it is to hear the transitional vowels
44. Inserting silence into speech
a. Say
b. a with 10 ms of silence inserted between /s/ and /e/ sounds
c. a with 20, 40, 60, 80, 100, 120, 140 ms of silence
45. Reasonable vs. ridiculous speech: yah yah, yah, faster and faster and . . .
46. Ara ala becomes arda alga with increasing amounts of silence inserted between the consonant and the final vowel. Inserted times are 0, 10, 20, 40, 60, 80, 100, 120, 140 ms
47. Gray ship, with editing silences and becomes gray chip, great ship, etc.



## Chapter 13

48. Scales with equal steps on the mel scale
a. Down the chromatic mel scale
b. Diatonic mel scale in the midrange
c. Diatonic mel scale in high range
d. Diatonic mel scale in low range
49. Mel scale music
a. Tune in middle mel scale pitches
b. a tune in lower mel scale
c. Original Bach tune
d. Mel scale version of c
50. Risset-like tones
a. Pitches are rising by major sevenths, but can be heard going down chromatically
b. Pitches are falling by sevenths, but chroma is rising by a major scale.
51. Height only
a. Height only, without chroma change, noise
b. Height only, without chroma change, string timbres
c. Height only, no change of chroma, sine tones
d. One more noise example
52. Shepard tritone paradox
a. Tritone can be heard as going up or down
b. Diminished thirds going upward give the context of "upwardness"
c. a repeated. Now likely to be heard as going upward
d. Diminished thirds going downward give context of "downward"
e. a repeated
53. Scrambled/stretched melodies
a. Familiar song with pitches placed in random octaves
b. Same song with melodic shape (up and down) preserved in choice of next octave
c. Song in original correct pitch height
d. Another song, octave scrambled
e. d stretched, but shape preserved
f. d in correct melodic spacing
54. Risset's ever-rising glissando
55. Original version of Shepard tone with discrete scale steps
56. Tempo illusions
a. Ever faster patter from a Risset composition
b. Example of fast trills from a Ligeti piece

57. More Shepard examples
 a. Variation on the Shepard tones, where fifth up, fourth down pattern is endlessly repeated
 b. Close canon in endless rise

## Chapter 14

58. Stretched scale/partials examples
 a. A few bars of a hymn played with normal scale and harmonic partials
 b. hymn played with stretched scale but normal harmonic partials
 c. hymn played with stretched scale and stretched partials
 d. hymn played with normal scale and normal partials (repeat of a)
59. Musical intervals with sines, versus complex waves
60. Nonlinear beating between sinusoids as described in section 14.5
61. C major triads in temperaments
 a. Just temperament
 b. Mean tone in C
 c. Just temperament
 d. Equal temperament
 e. Just temperament
 f. Mean tone in C
 g. Mean tone in C♯
 h. Mean tone in C
62. Pierce scale examples

## Chapter 15

63. Categorical perception, a wren warbling (three different "utterances")
64. Probe-tone studies, diatonic scale
 a. Diatonic scale up, with no octave
 b. First probe tone to play after a
 c. Same as a
 d. Second probe tone to play after c
65. Probe-tone studies, musical context
 a. Cadence without arrival on tonic
 b. Probe pitch that is remote from intended end of cadence of c
 c. Same as a



 a. C scale in which all intervals are wide, so that the octave C is actually a C♯
 b. Probe tone C, which is actual starting note of a
 c. Repeat of a
 d. Probe tone C♯ an octave below to match end of a
67. Equalized scale
68. Gamelan orchestra examples
 a. Gamelan musical example
 b. Sample tune in Bali tuning
 c. Probe ending to b
 d. Repeat of b
 e. Another probe ending to b
69. One more probe-tone example
 a. Melody in Western scale
 b. Probe ending to a
 c. Repeat of a
 d. Another probe ending to a

## Chapter 16

70. Synthesized singer
 a. No vibrato
 b. With random and periodic vibrato, and singer scooping slightly upward at the beginning of each note
71. Normal to ridiculous articulations
 a. Vocal
 b. Trumpet playing

## Chapter 17

No sound examples

## Chapter 18

No sound examples

## Chapter 19

No sound examples

## Chapter 20

72. A periodic tone, followed by a quasi-periodic tone
73. Building a soprano tone. First a G-pitched sinusoid, then harmonics are added, followed by vibrato.
74. Like 73, but on B pitch
75. Like 73, but on D pitch
76. Mixture of 73, 74, and 75, but with different vibrato functions on each "voice"
77. FM synthesis example that transforms a bell to three voices, then back to a bell timbre. The three voices are drawn out by applying separate vibrato functions to them.
78. Perception of distance and effort
   a. Successive vocal tones, where amplitude is turned down with each note. Relation of harmonics remains constant, like turning down volume on stereo.
   b. Same sequence as a, but high end of spectrum is successively lowered, as would happen for decreasing effort.
   c. Same as b, but additionally the ratio of reverberation to direct sound is held constant, so voice sounds like it is getting quieter in a fixed location.
   d. Same as a, but the ratio of reverberation to direct sound is increased, so voice sounds farther and farther away.

## Chapter 21

79. String sounds by Scott A. VanDuyne
   a. Plucked string with no nonlinear effect, followed by four plucked string sounds with gradually increasing nonlinear effect
   b. More extreme nonlinear string sounds
80. Membrane (drum) sounds by Scott A. VanDuyne. Without, followed by with, non-linearity. Then a variety of different excitations and amounts of non-linearity

Following the audio examples on this CD, there is a data segment that includes ANSI C code for generating many of the sound examples on the CD. There are also a number of MIDI level 0 files for performing experiments/demonstrations in real time. The authors hope that these code and data files are useful to those wishing to do their own experiments.

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