Music Perception & Cognition

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(Image removed due to copyright considerations.)
Outline

• Course mechanics
• Class survey
• Music, mind, and brain
  – FORM & QUALITY
  – PATTERNS OF EVENTS IN TIME
  – NEURAL MECHANISMS
  – MEMORY/GROUPING
  – EMOTION/MEANING
  – ORIGINS
• Overview of topics
• Music introduction

Handel, S. 1989. Listening: an Introduction to the perception of Auditory Events. MIT Press. REQUIRED.

Snyder, Bob. 2000. Music and Memory. MIT Press. REQUIRED.


Course rationale(s)

• Music is an important aspect of the auditory sense that rivals speech and language in complexity
• Many of us come to auditory research through a native interest in music
• Music affords an alternative perspective on hearing and neuroscience, spanning acoustics, sensory physiology, auditory perception & auditory cognition
• We strive to be systematic and integrative in our treatment (lecture format)
• a primary goal is to facilitate intellectual synthesis; to organize disparate facts into coherent wholes
• We want students to choose & formulate their own problems, articulate their own perspectives, and delve deeply into an area of personal interest (term projects)
Organizing themes: Music, mind, and brain

- FORM & QUALITY OF SOUNDS (tones)
- PATTERNS OF EVENTS IN TIME (events)
- NEURAL MECHANISMS
- MEMORY & ORGANIZATION
- EMOTION & MEANING
- ORIGINS: Why music?
Auditory qualities in music perception & cognition

- **Pitch**  
  Melody, harmony, consonance

- **Timbre**  
  Instrument voices

- **Loudness**  
  Dynamics

- **Organization**  
  Fusions, objects. How many voices?

- **Rhythm**  
  Temporal organization of events

- **Longer pattern**  
  Repetition, sequence

- **Mnemonics**  
  Familiarity

- **Hedonics**  
  Pleasant/unpleasant

- **Semantics**  
  Cognitive & emotional associations
Basic auditory qualities
Dimensions of auditory perception

FUSION
Grouping into separate objects
Temporal co-occurrence
Harmonic structure

TEMPORAL EVENT STRUCTURE
Meter, sequence

John Lurie
Car Cleveland
Music from Stranger than Paradise
Music: patterns of events in time organized relations between events

Ludwig van Beethoven
Bagatelle
Opus 33, no. 5

Please see Mark Malinowski’s Music Animation Machine Site (http://www.well.com/user/smalin/mam.html)
From cochlea to cortex

10,000k
Primary auditory cortex
(Auditory forebrain)

Auditory thalamus

500k
Inferior colliculus
(Auditory midbrain)

Lateral lemniscus

Auditory brainstem

30k
Auditory nerve (VIII)

3k
Cochlea
MECHANISM

Neurophysiology  Music cognition
Neurocomputation  Music theory
Neurophysiology
Neurocomputation
Neural responses
Neural codes
Neuroanatomy
Psychoacoustics
Reverse-engineering
Explaining pitch

Music cognition
Music theory
Schemas, grammars
Event structures
Tonal hierarchies
Memory
Aesthetics, hedonics
Pitch as a primitive
Visual Grouping: Proximity Principle

Acoustical grouping


SIMILARITY

Sequential Grouping
(Arrows indicate point of realization of change.)

- Change in loudness
- Change in timbre
- Change in pitch interval

Simultaneous Grouping

Figure 3.5
Acoustical grouping.
Melodic & rhythmic grouping


Figure 3.3
Melodic and rhythmic grouping.
Rhythmic Hierarchy

Emotion & meaning in music

Psychological functions of music: why we do it
• Perceptual-cognitive interest (formalism)
• Mood control & emotional expression (expressionism)

The meaning of meaning: semiotics

Sources of meaning: reference and/or construction
• External env. associations: linkages w. memories
• Lyrics and their semantics
• Internal associations: body rhythms, patterns
• External musical associations, expectations (e.g. dirge)
• Intrinsic music expectations (harmonic & rhythmic org.)

What cues convey emotional meaning in music?
Harmony, rhythm, dynamics, expressive timing

Is the minor key (intrinsically) sad?
Tentative schedule: February 3-10

Tuesday Feb. 3 (Cariani)
Course mechanics
Survey of topics to be covered
Overview of the structure of music

Thursday, Feb. 8 (Cariani)
Overview of auditory perception and the time sense: pitch, timbre, consonance/roughness, loudness, rhythm, auditory grouping, event structure
Overview of the auditory system: Representation and processing of sounds in the auditory pathway

Tuesday, Feb. 10 (Cariani)
Musical acoustics
Musical pitch
February 12-24

Thursday, Feb 12 (Oxenham)
Psychoacoustically-based theories of hearing

Thursday, Feb. 19 (Cariani)
Representation of pitch in the auditory system
Neurocomputational models for pitch
Licklider, Terhardt, Grossberg & Cohen, Bharucha
Equivalence classes and octave relations; Neural evidence pros & cons

Tuesday, Feb. 24 (Cariani)
Timbre
February 26-March 11

Thursday, Feb. 26 (Cariani)
Harmony I: Consonance, dissonance, and roughness
   Theories: Helmholtz, Stumpf, Plomp, Terhardt
   Sensory and hedonic aspects
   Neural correlates (auditory nerve, midbrain, cortex)

Tuesday, March 2 (Cariani)
Scales and tuning systems
   History, basic psychophysics, scales and tuning systems, role in music theory
   Relations between auditory and cultural factors

Tuesday, March 9 (Tramo)
   Results of imaging and lesion studies. Hemispheric asymmetries.

Thursday, March 11 (Cariani)
Harmony II: chords and keys
Tuesday, March 16 (Cariani)
Presentation and discussion of term projects

Thursday, March 18 (Cariani)
Melody

Tuesday, March 30 (Cariani)
Rhythm I: Rhythm perception and production
Rhythm II: Computational models

Thursday, April 1 (Cariani)
Time perception, event structure, and temporal expectations
Auditory scene analysis and organization of voices
Grouping of sounds – onset, harmonicity, rhythm
Grouping processes and musical structure
April 6-15

*Tuesday, April 6* (Cariani)
Music, speech and language: parallels and contrasts (Bernstein, Jackendoff)

*Thursday, April 8* (Cariani)
Emotion and meaning in music
Musical semantics, music and pleasure
Music and long-term memory

*Tuesday, April 13* (K. Howland, music therapist)
"Clinical applications of the neuropsychology of music." Guest speaker Kathleen M. Howland Ph.D., MT-BC, CCC-SLP.

*Thursday, April 15* (Oxenham)
April 22-May 13

Tuesday, April 27 (Cariani)
Developmental psychology of music
A question of origins: comparative and evolutionary psychology of music

Thursday, April 29 (Cariani)

Tuesday, May 4 (Cariani)
Special topics: absolute pitch, synesthesia, etc.

May 6-11
Student Term Project Presentations

Thursday, May 13 (Cariani)
Overview and recap of major themes; other special topics
An Introduction to Music: Sound unfolding in time

(Image removed due to copyright considerations.)
Sound unfolding in time: an introduction to music

• Music: a bird's eye view; provisional definition
• Ubiquity of music: Nature and nurture
• Sound unfolding in time
  – Horizontal dimension (time, sequential sounds)
    • Melody (Temporal patterns/sequences of pitches)
    • Chord progressions, key modulations (Temporal patterns/sequences of pitch relations)
    • Rhythm (Temporal patterns/sequences of events)
  – Vertical dimension (sound quality, concurrent sounds)
    • Pitch (Dominant periodicities) & Timbre (spectrum, frequency microdynamics)
    • Harmony (Constellations of concurrent pitches)
  – Number of independent trajectories: voices, streams
• Relations to perceptual dimensions
• Psychological questions
Music as stimulus, idea, action, and private experience

Psychology of music examines relations between music and mind.

Music is half of this relation.

Mind has different facets:
1st person experience
3rd person overt behavior
Underlying neural activity
Functional organization of informational processes
Music: a provisional definition

Deliberate organization of patterns of sound for interest or pleasure. Deliberate organization of auditory experience for interest or pleasure.

"Organization" can involve composition or performance or selection of sounds or even selective attention to sounds (Cage) "Interest" and "pleasure" are similarly very broadly construed.
Music has been part of human culture for > 40,000 years
Every known extant culture has some form of music
Many cultures equate musical with social harmony (Greeks)
Relative contributions of nature (biology) & nurture (culture) to the experience of music.
A great deal of diversity exists across cultures in the forms music takes (ethnomusicology)
There are universals related to how we hear that are given by biology (auditory science).
But there are also the effects of culture-based training of how we hear (what aspects we attend to).
There are also culturally-specific interpretations and meanings associated with what is heard.
In these lectures we will focus mainly on the universals -- basic aspects of music that are shared across cultures.
We want a general framework for talking about music that can encompass both the Western tonal music (classical, jazz, popular) as well as all the traditional musics of the world.
Horizontal and vertical dimensions

Tonal quality
(pitch, spectrum)

Time (beats, seconds)

http://www.well.com/user/smalin/compare.htm
Horizontal dimension (time)
Temporal patterns and sequences of sound-changes
Melody: temporal patterns of pitches
Cadences, key modulations:
  temporal patterns of pitch constellations
Rhythm: temporal patterns of events
Bernstein on musical intervals and dimensions
  Does music require discrete perceptual "atoms"?
Horizontal dimension (time)
Different musical cultures utilize different aspects of musical possibility. Ethnomusicologists, anthropologists, and historians have theories as to why cultures adopt particular musical styles.

Examples of music that are focused on melody.
(Traditional fiddle-playing in France -- video)
(Gasparyan, Armenian flute music)
Indian ragas

Examples of musics focused on chord progressions
Western symphonic "classical" music, Rock

Examples of music focused on rhythm
African drumming (many examples)
Mbira music, Senegal -- video
Vertical dimension (Harmony)

Patterns of concurrent sounds
Constellations of pitches (intervals, chords)
Sound texture (timbre)

Number of independent voices

Example of horizontal and vertical organization:
   Satie Music Animation Machine

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Horizontal dimension involves temporal context & memory
Build-up of representations and expectancies
Vertical dimension involves tonal interactions
Masking, fusions of sounds
Rethinking the role of time

• Time as coding auditory quality (pitch, timbre, rhythm)

• Time as metrical structure of events
  Repetition and change in music
  Buildup of temporal pattern expectations

• Time as ordinal sequence of events

Perception
  cognition
  &
  Motor
  domains
Basic auditory qualities
Dimensions of auditory perception

- Pitch
- Location
- Timbre
- Loudness

TEMPORAL EVENT STRUCTURE
- Meter, sequence

FUSION
- Grouping into separate objects
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- **Loudness** Dynamics
- **Organization** Fusions, objects. How many voices?
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- **Hedonics** Pleasant/unpleasant
- **Semantics** Cognitive & emotional associations
Sound Waveforms Power Spectra Autocorrelations

Formant-related Pitch periods, 1/F0
Vowel quality Timbre

[ae] F0 = 100 Hz
[ae] F0 = 125 Hz
[er] F0 = 100 Hz
[er] F0 = 125 Hz

Time (ms) Frequency (kHz) Interval (ms)

0 10 20 0 1 2 3 4 0 5 10 15

0 5 10 15
Frequency tuning of Auditory Nerve Fibers as a function of CF

Figures adapted from a figure by Alan Palmer (From Palmer and Evans, unpublished data.)
Phase-locking in auditory nerve fibers
Phase-locking to a 300 Hz Pure Tone

Stimulus Waveform (0.3 kHz)

Period Histogram (1100 Hz)

First-order Interval Histogram

1.1 kHz 90dB SPL

1.5 kHz 80dB SPL
Frequency ranges of (tonal) musical instruments

- **Bass**
- **Violin**
- **Bass voice**
- **Soprano voice**

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<th>Frequency (Hz)</th>
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<tbody>
<tr>
<td>27</td>
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<td>110</td>
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<td>262</td>
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<td>440</td>
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<tr>
<td>880</td>
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<td>4 kHz</td>
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Reading for Thursday

Deutsch: Weinberger Chapter
Handel: pp. 461-488