Clap along
How did you know when to clap?  

*beat or tactus*

**Tactus:** a basic pulse
- Rate at which we spontaneously tap while listening to music.
- Evenly or regularly spaced.
- Typically falls in the range between 0.6 and 0.75 seconds (80 to 100 events per minute).
- Commonly coincides with the beat rate but remains an undifferentiated pulse.

**Beat:**
- A recurring moment when tone onsets are more expected.
- Strong - weak differentiation.
- Occurs within a repeating pattern of beats - *meter.*
How do we identify them?

Most are highlighted or accented

– Clear onsets
– Relatively loud
– Notes played are usually harmonically important
– Low down in the texture, the bass line is bringing them out

• Quick
Tap along

We readily insert additional beats and form a metrical structure. Even when the rest of the information doesn’t match/support it, our tapping is not merely responsive.
How do you know it’s the beginning of the bar?

- Repetition / Parallelism
- Loudest
- Longest
- Lowest
- Strong base notes
- Cadences
- Suspension (on strong beat)
- Alternating strong / weak

Formalised in Lerdahl and Jackendoff
Human perception of musical structure

Digital Signal Processing with Computer Music
Dr Neta Spiro
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Human perception of musical structure

• Rhythm and time
  – Metrical structure
  – Time and memory

• Musical pitch in cognition
How do we recognise the metrical structure?

• Building on first beat identification

• Hierarchy of beat strength in the bar
  – e.g. binary vs. ternary

• Relationship between bars
Temporal Awareness

How are we aware that time has passed?

→ Through the perception of CHANGE
Temporal Awareness

Change may be:

• **External**: aware of events occurring in the environment (Heraclitus, Plato)
• **Internal**: aware of changes in our own proprioceptive state (James 1890)
• **Mental**: psychological awareness of duration (Bergson 1911, Langer 1953)
Temporal Awareness

Or, “Events are perceivable; time is not”

(Gibson 1975)

→ The events that are most salient in music perception are sound onsets.
Some constraints on our experience of things (music) happening in time

• Temporal resolution
• Engagement
• Amount of processing
• Schemata
• Predictions
• Memory
• Complexity
• Similarity
The perception of time

limit on "grain" of temporal perception

0.005 sec       0.05 sec         0.5 sec           5 sec            1 minute        1 hour         ????

span of working memory or perceptual present

Short-term memory for events and event-structures

Long-term memory
“The experience of a duration of a [time] interval is a construction formed from its ‘storage size’ - as storage size increases the experience of duration increases.”

Ornstein, 1969, p. 42

Time and Memory

• “Storage size”
  – Rate of events
  – Attentiveness
  – Other events
Time and Memory
Dynamic Attending (Jones 1986, Jones and Boltz 1989)
Focal attending

Future-oriented attending

Reference level

reference period (preferred tempo)

Analytic attending

Focal attending

Metre
Four ‘levels of analysis’
Lerdahl and Jackendoff

• Metrical
  – Based on principles of binary & ternary hierarchy
  – Strictly limited in terms of the levels to which the hierarchy might extend,

• Grouping
  – Structure largely predicated on events at the level of the musical surface
  – Includes groups of many sizes, including the “phrase”
  – Chunking
Four ‘levels of analysis’

• Metrical and Grouping Rules
  – Largely derived from musical surface
  – More determined by the musical stimulus and general aspects of our perceptual systems than by any specifically (schematically learned) musical considerations,
  – Though musical considerations can play a role (esp. in grouping).
Temperley

A preference rule system evaluates many possible interpretations and chooses the one that best satisfies the rules for meter, phrase structure, contrapuntal structure, harmony, and key, as well as pitch spelling.

Preference rule systems not only show how musical structures are inferred, but also shed light on other aspects of music: musical ambiguity, retrospective revision, expectation, and music outside the Western canon (rock and traditional African music).
Temperley proposes a framework for the description of musical styles based on preference rule systems and explores the relevance of preference rule systems to higher-level aspects of music, such as musical schemata, narrative and drama, and musical tension.
Rhythm and time

Summary

• We readily (and quickly) hear and respond to a pulse in music (and other info)
• We readily hear a metrical structure in music (and other info)
• For both of these we use cues in the music
• Together they are part of a multi-levelled structure

• We can generate our own pulse independently of music or with it
• Theorists such as Jones and Lerdahl and Jackendoff have summarised patterns of behaviour and some theories
Musical pitch in cognition
Complex waveforms - additive synthesis

- $f_1$
- $2f_1$
- $3f_1$
- $4f_1$
- $5f_1$

Spectrum of $f+2f+3f+4f+5f+6f+7f+8f$:

- $\frac{f}{2}$
- $f$
- $2f$
- $3f$
- $4f$
- $5f$
- $6f$
- $7f$
- $8f$

Sawtooth waveform
≠

Complex waveforms - additive synthesis

Sawtooth waveform

Spectrum of f + 2f + 3f + 4f + 5f + 6f + 7f + 8f
• How do we learn pitch relationships and functions?
  – Inherent characteristics of the frequencies we hear?
  – Proportion of time you hear pitch relationships and associated functions?
  – Long term memory?
  – Short term and on the fly?
ACTUAL WORLD
(POTENTIALLY AVAILABLE INFORMATION)

ACTUAL PRESENT ENVIRONMENT
(AVAILABLE INFORMATION)

MODIFIES

DIRECTS

SAMPLES

DIRECTS

ACTION

DIRECTS

PERCEPTUAL EXPLORATION

DIRECTS

ATTENTION

DIRECTS

GENERIC PREDISPOSITIONS

DIRECTS

LONG-TERM MEMORY

MODIFIES

SCHEMA OF PRESENT ENVIRONMENT

DIRECTS

DIRECTS

DIRECTS

DIRECTS
Auditory Scene Analysis

• What do we do when we hear something as a melody?
Figures presented

XO XO XO XO
XO XO XO XO
XO XO XO XO

Figures perceived

law of proximity
XO XO XO XO XO
XO XO XO XO XO

law of similarity
XO XO XO XO XO
XO XO XO XO XO

law of good continuation
The formation of auditory streams: interaction of rate of occurrence and pitch separation

- **Always segregated**
- **Always coherent**
- **Ambiguous**
Auditory scene analysis

• ‘...is the process whereby all the auditory evidence that comes, over time, from a single environmental source is put together as a perceptual unit' (Bregman, 1993).
Auditory scene analysis

- Acoustical
- Psychological
  - Psychoacoustical: primarily concerned with the ways in which our auditory sensory apparatus (outer, middle and inner ear and associated neural structures) transforms acoustical information into the 'language of the brain', neural impulses.
  - Cognitive: more concerned with the ways in which this neural information comes to have a functional significance for us.
Cognitive approaches to pitch
Cognitive structuralism
Cognitive dimensions of musical pitch

Chroma circle

Circle of fifths

Pitch height dimension (as linear continuum)

Pitch height dimension (as discrete linearly-organised categories)

https://recursivearts.com/virtual-piano/
RATINGS of FIT

C  C#  D  D#  E  F  F#  G  G#  A  A#  B

after Krumhansl, 1990
Units and links in Bharucha's MUSACT system.
Cognitive approaches to pitch
Intervallic rivalry theory

• Long term vs. short term memory
• Dynamic vs. static attributes of tonal structure
• Intervals rival model
  – Centres on processes of key discovery,
• Cognitive-structuralist account
  – Centres on processes of reinforcement of tonal function.

• Both necessary for a listener to follow tonal music in real time.
• "psychology of ear training"
  – not
• "psychology of music"

Cook 1994
Summary

• It's likely that all these processes –
  – of auditory scene analysis, of the abstraction and
schematicisation in long-term memory of
regularities of musical pitch organisation, (as well
as of the abstraction of the 'virtual roots' and
relative stabilities of chords)

• play significant and determinant roles in our
experience of pitch organization in music.

Cross 1997
What would a theory of our perception of musical pieces take into account?

- Several theories have been proposed.
- Don't have a comprehensive theory that deals with all the different processes that seem to be going on when we experience a piece of music.
Language and linguistics

Computer Science & AI

Anthropology

Neuroscience

Psychology

Child development

Education

Medicine

Music Therapy

• Pitch
• Rhythm
• Time
• Phrasing
• Movement
• Language
• Emotion
• Development
• Performance (improvisation)
• Musicians’ health
• Brain
• Body
• Evolution
• Health & wellbeing
• Daily life

Musicology

Ethnomusicology

Performance

Dance / Dance psychology
Some reading

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