

Topic Summaries for HST.725 2009 Peter Cariani

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Overview of the Course

We cover the psychological uses of music first -- why we listen, what functions music fulfills for us in our lives. The rest of the course examines the properties of sound, patterns of musical events, and the nervous system that allow music to fulfill these functions. The plan of the course is to cover the perceptual psychology of music first, going from basic elements of sound and dimensions of perception (pitch, timbre, loudness) to interactions of notes (consonance, melody, harmony) to patterns of events (rhythm, larger patterns). We then get into the affective psychology of music -- emotion and meaning, and we are trying to relate all this to what is going on in the brain. Here we are trying to answer the basic question of why music has its manifold psychological effects on people, and specifically how it does it.

Psychological functions of music

Provisional definitions of music
What is a psychological function?
The many uses of music in everyday life
Course mechanics

What you should know
The problem of defining what music is
Functional definitions (e.g. organization of sound for pleasure or interest or other purpose(s))
Uses of music -- how people use music in their lives, in societies
Psychological functions of music -- what goals are achieved by listening/playing music
e.g. mood control, stress/pain reduction, cognitive interest, distraction, motivation, dance, exercise, meditation, spirituality, identity assertion, aesthetics, etc.

Social-psychological roles of music

e.g. in rituals, economics, entertainment, status, setting context, nonverbal communication, cooperation, bonding, coordination, protest/dissent, group identity

Musical Sound

Basics of sound & vibration

Waveforms

Frequency spectra, Fourier analysis

Spectrograms

Harmonics and periodic sounds

Oscilloscope & spectrogram demonstrations

What you should know:

What is a waveform (a time-series, i.e. a series of numbers on a timeline)

What is a spectrum (a plot of the frequency composition of a sound)

All sounds can be broken down into combinations of sinusoids (pure tones)

These component pure tones are called partials

What a spectrogram shows (frequency spectrum vs. time)

Pure tones (one frequency) and complex tones (multiple partials)

Fundamental frequencies and harmonic series

Harmonic vs. inharmonic sounds

Impulsive (transient) vs. sustained sounds

General concept of resonance

Auditory System Overview

This is a very basic lay-of-the-land introduction to the auditory system, going from the ear to the cerebral cortex.

What you should know:

The function of the nervous system is to sense the state of the world and to coordinate behavior in a manner that supports survival and reproduction.

The nervous system is a signaling network.

The signals of the network are trains of pulses.

Neurons are cells specialized for communications.

Neurons transmit signals by sending trains of pulses -- action potentials ("spikes").

Dendrites are the collector parts of the neuron -- they receive signals from other neurons via molecular-messenger connections (synapses).

Synaptic inputs sum together and trigger spikes in axons -- the neuron "fires" off a spike.

Axons function as active transmission lines for spike trains. They are like wires.

Each axon has a tree of terminal branches with synapses that make connections with the dendrites of many other neurons.

The problem of the neural code involves understanding how information is encoded in patterns of spikes amongst neurons. We seek to understand the nature of the "signals" that the nervous system uses.

Some codes involve which neurons fire how often (firing rate codes), while other codes involve the temporal pattern of firing (temporal codes).

The auditory system has much in common with other sensory systems.

The ear consists of three parts: outer ear (pinna), middle ear (ossicles), and inner ear (cochlea). The outer ear shapes sound for localization (elevation), the middle ear is a set of levers that adapts the air vibrations at the eardrum to drive the fluid-filled, hydraulic cochlea.

The cochlea is a frequency-tuned structure -- different parts of the cochlea resonate to different frequencies of vibration.

Sound is converted from mechanical vibration to fluctuating electrical currents in the cochlea by sensory receptors called inner hair cells.

Spikes are produced in the axons of neurons of the auditory nerve that are connected to these hair cells by chemical synapses.

The auditory nerve (cochlear nerve) is a bundle of 30,000 neurons in humans that conveys information from the cochlea to the central nervous system (brainstem).

Ascending pathways convey volleys of spikes upwards from the brainstem to the midbrain to the thalamus to the cerebral cortex in a series of steps.

There are also descending pathways that convey signals downward, from the cortex to thalamus to midbrain to brainstem and even to the cochlea. Efferent pathways to the cochlea and middle ear muscles function like a gain-control (volume control) mechanism.

The basic plan of the auditory system is the same across mammals. Smaller animals tend to hear higher frequencies than we do, while larger ones hear lower frequencies. Our range of hearing is approximately 20-20,000 Hz.

Dynamic range is the ratio of the sound pressure level of the most intense (loudest) sound we can hear to that of the least intense (softest) sound we can hear. The upper limit of this range is usually set at the threshold of pain. The lower limit is the threshold of hearing.

The dynamic range of the human auditory system is on the order of 100 dB (a factor of 100,000).

Psychophysics (or here psychoacoustics) is the study of the relation of physical parameters of stimuli to their perception. The acuity of hearing is measured in terms of what changes in acoustic parameters can be discriminated (distinguished). A common measure of acuity is the "just-noticeable-difference" or jnd. For pitch this is measured in Hz; for loudness, this is usually in dB. The Weber fraction of a percept is the percent change of some parameter that can be detected/discriminated. For example the Weber fraction for frequency (pitch) would be $(\Delta f/f)$, where Δf is the just-noticeable difference in Hz, divided by the pitch frequency f .

We know a great deal about the nature of the neural information at the level of the auditory nerve, but the precise nature of neuronal representations of sound at the cortical level is still unknown. There are many unanswered questions as to exactly how the auditory system works.

Pitch

The lecture on pitch is by far the most intense foray into the nitty-gritty of neuroscience that we will encounter. The neurology of music that we will deal with later in the course is much more qualitative and simple, mostly because we know much less about the nature of the underlying neural signals.

We started out with some basic observations about loudness and sound intensity in music.

Absolute sound levels are usually expressed in dB SPL.

We can detect changes as small as 1 dB (12%) in amplitude.

Sustained exposure to sound at over 100 dB SPL will cause permanent hearing damage.

Loudness is relevant to music in terms of 1) listening level 2) loudness contrast, accented events, and rhythmic grouping 3) musical dynamics (crescendos, diminuendos) and 4) effect of intense sounds on hearing impairment (auditory safety).

Pitch forms the basis for melody and harmony in music. Tonal music in the widest sense of the term is music that depends on patterns of pitches. Tonal music as opposed to atonal music in the Western tradition, is music in which particular pitches and pitch relations are favored (tonal centers: tonics and keys).

We discussed the neural coding of pitch in the auditory nerve. This is important for the perception of music because it likely forms the basis for our ability to perceive pitch, the structure of harmony, and the mechanisms that group and separate sound components to form individual voices.

There are two kinds of codes, a rate code and a time code. In the rate code, often called a "rate-place code", particular auditory nerve fibers respond to particular frequencies. In the time code, temporal patterns of spikes are produced by the time pattern of the stimulus waveform. The rate code produces a crude representation of the stimulus spectrum, while the time code produces a very precise representation of the stimulus time structure.

The time code produces representations of sound that are stable over the whole dynamic range of hearing.

At the level of the auditory nerve, the neural code for musical pitch appears to be based almost completely on a time code.

The range of musical tonality extends from about 30 Hz to about 4,000 Hz, which is approximately the frequency range of the piano. This coincides with the upper frequency limit of the time code, which is also about 4,000 Hz.

The time code is based on times between spikes -- interspike intervals -- that reflect the periodicities in the stimulus acoustic waveform. The interspike interval that is the most common in the auditory nerve array at any particular time corresponds to the pitch that is heard.

The basic reason that this happens is as follows (you don't need to know this). Each frequency in the stimulus produces a series of interspike intervals that are related to the subharmonics of that

frequency. For a harmonic complex tone, when you add up all the subharmonics of all the harmonics, the fundamental frequency is the subharmonic that wins out.

The code for pitch predicts how strongly multiple sounds will fuse together (one aspect of consonance) and may also predict how perceptually stable the pitches of chords are. This pitch-stability of chords in turn relates to harmonic tension and relaxation in chord progressions that lead from the stable chords (e.g. major triad) to less stable chords, and back.

Timbre

We covered the auditory attribute of timbre.

What is timbre? Tone quality or "color" that distinguishes different instruments or voices sounding the same note (pitch, duration, loudness, location).

Functions in music: 1) separate and identify distinct voices, 2) add coloration to sound, 3) design and build musical instruments with particular sound qualities, 4) use a primary dimension of sonic change (e.g. sound mass, electronic music, lexical music, ambient music)

Acoustic correlates of timbre

- 1) for stationary sounds -- features of the frequency spectrum
 - a) formants, resonances, spectral peaks (e.g. vowels)
 - b) spectral tilt (higher frequencies = brighter, lower frequencies = darker)
- 2) for sounds that change rapidly
 - a) amplitude dynamics (attack, decay, sustain, release, tremolo)
 - b) frequency dynamics (glides, frequency modulation, order of harmonics appearance)
 - c) phase dynamics
 - d) analogy with consonants in speech

Methods;

Similarity ratings and multidimensional scaling

Analysis through synthesis (Jean Claude Risset)

Do look at the Wikipedia definition of timbre if you want a quick overview.

Consonance & dissonance

This lecture covers basic concepts of consonance and dissonance, which are properties that depend on interactions between notes.

Consonance and dissonance are important because they are properties of musical intervals (F0-ratios and frequency separations between notes) that give particular combinations of notes (musical intervals) special attributes.

One could say that consonance is the basis of harmony.

"Consonance" as a term can mean different things to different people, so it is important in psychophysical studies to ensure that subjects are attending to those particular aspects that one wants to study. Common attributes associated with the term "consonance" are pleasantness, euphoniousness, harmoniousness, smoothness, lack of roughness, tonal unity, stability. It's important to separate the hedonic aspects of consonance (pleasantness or preference for particular intervals) with perceptual aspects (roughness or fusion, stability).

Consonance and dissonance are properties of musical intervals, whether the intervals are made up of concurrent notes (vertical intervals) or sequential notes (horizontal intervals). The existence of recognizable horizontal intervals is due to short-term pitch memory in the auditory system, which compares incoming notes with those last heard (i.e. "musical context"). Consonance perception can also be affected by learned, cultural expectations, i.e. which musical intervals are more familiar.

From antiquity, it has been recognized that sounding two strings with simple frequency ratios (2:1 octave, 3:2 fifth, 4:3 fourth) produce notes that tend to blend together smoothly and "harmoniously" whereas those with more complex ratios (16:15 minor second, square root of 2 -- the tritone) sound rougher and more discordant.

The main theories of consonance involve the interactions of harmonics of the two notes 1) that cause roughness or beating (Helmholtz' theory) and 2) that result in greater or lesser degrees of tonal fusion, pitch unity, pitch stability (Carl Stumpf's theory). Often theories of roughness are put under the rubric of "sensory dissonance". Because sequential notes do not interact in the cochlea to produce roughness and beating, most roughness theories do not account for the consonances and dissonances of sequential notes (horizontal, melodic consonance).

There are neural correlates for both kinds of theories in the temporal firing patterns of auditory nerve fibers. Beating harmonics that evoke roughness percepts cause firing rates of auditory nerve fibers sensitive to those frequencies to fluctuate in time with the beating. Fusion, on the other hand, is related to patterns of interspike intervals and whether these cooperate to produce unified pitches or whether they compete to produce multiple pitches. There are also spectral pattern models (Parncutt) that rely on patterns of common harmonics and subharmonics.

We saw that simple ratios of frequencies (octave, fifths, and fourths) produce strong, unified pitches at the fundamental frequency of the two note combination (this is the "fundamental bass" of the note dyad, of the musical interval).

I showed some of the results of a pitch model that predicts the pitch stability of various musical intervals for dyads and also triads. This leads then into notions of relative pitch stabilities of chords and their relative degree of tension (instability) and relaxation (stability). The major triad is the most stable, followed by minor triads, and then by (dissonant) diminished and augmented chords. The typical chord trajectories of western tonal music, first establish a tonal center or base (the tonic), and then venture away from the stability of the tonic using more dissonant chords to build tension, and then finally return back to the tonic (relaxation). Consonance, thus, is the perceptual basis of the establishment of harmonic, tonal centers, the buildup of harmonic tension, and its release.

Consonance plays an important role in the construction of musical scales. Generally, it is important to include both consonant and dissonant intervals in the scale (for contrast) and to approximate the ratios of the consonant intervals (octave, fifth, fourth, and to a lesser extent thirds and sixths) as best one can. Just tuning systems base their tunings on these ratios, but do not allow free modulation to other keys (because these other keys will sound out of tune -- they don't preserve the ratios). Equal temperament with 12-chromatic notes in the octave (12-TET) is a compromise between these two design goals that works quite well.

What you should know:

What is a musical interval

Prominent musical intervals (octaves, fifths, fourths)

Consonant intervals (octaves, fifths, fourths)

Dissonant intervals (seconds, sevenths, tritones)

Roughness and its basis in harmonics that beat together -- more roughness = more dissonance

Fusion and its basis in pitch representations, more fusion = more pitch stability

Consonance plays an important role in the construction of musical scales

Scales & Tuning

Scales are the set of pitches that are used to construct melodies and harmonies.

Diatonic scales consist of seven notes in the octave, while chromatic scales consist of 12 notes.

Virtually all scale systems are constructed within the octave (2:1 frequency ratio), because of the perceptual similarity of notes an octave apart.

As we noted before, some frequency ratios (3:2, 4:3) between harmonic complex tones are more consonant than others. Tuning systems have traditionally been based on tuning by ear, which results in simpler frequency ratios. Just tuning involves sets of note intervals that are defined in terms of ratios between integers (e.g. 2:1, 3:2, 4:3, 5:4, 6:5, 5:3). A problem with just tuning is that if one changes key, the note relations are apt to be noticeably off these ratios, which has the effect of giving different keys different tonal qualities. This problem was solved c. 1600 by the invention of equal temperament in which note steps involve equal ratios such that the notes are equally spaced within the octave. In Western music the octave has been divided into 12 notes (12-TET), which provides a very close approximation to most important just tuned intervals, particularly the fifth (3:2) and the fourth (4:3).

In Western tonal systems, the major and minor diatonic scales are used to define tonal centers (the tonic, the first note in the scale) and sets of related pitches. These are called keys. Different subsets of 7 pitches in diatonic scales are possible -- in musical notation, these are indicated by key signatures. The "Circle of Fifths" shows which keys are related by the notes that they have in common (each step around the circle is a difference of 1 note that the neighboring keys do not have in common). Provisionally, the circle of fifths, can be taken as a surrogate for subjective key similarity (we will discuss psychological experiments by Carol Krumhansl in this context).

We also present some examples of music based on modal scales that are different from the usual major and minor scales of more modern western music. These illustrate the role of the tonic and

the anchoring of the scale to the tonic -- how changing the notes and the note-tonic relationships can change the "feel" of the tonality.

What you should know: pretty much everything in this summary

Melody & Harmony

In this lecture, which spanned two class meetings, we discussed melody and harmony. Melody involves sequences of pitches that unfold in time (horizontal dimension), while in its most general sense, harmony involves interactions between pitches, be they concurrent (vertical dimension) or sequential (horizontal dimension). Although "harmony" is often used in a more narrow sense of sets of concurrent pitches (chords), a melodic sequence of pitches has harmonic structure by virtue of short term auditory memory processes that compare incoming pitches with those that have occurred within the last few seconds.

We talked a bit about what defines a musical style -- the character of the melody, the chord progressions and harmonies involved, the tempo and rhythmic patterns, instrumentation (timbre) and voices, dynamics. Arguably, melody is the most distinctive aspect of a musical piece -- a melody can be combined with different harmony and rhythm accompaniment and still be recognizable as essentially the same tune. If one uses the same rhythmic pattern or chord progression, but a different melody, the musical pieces will sound very similar, but one might not recognize them as the same tune.

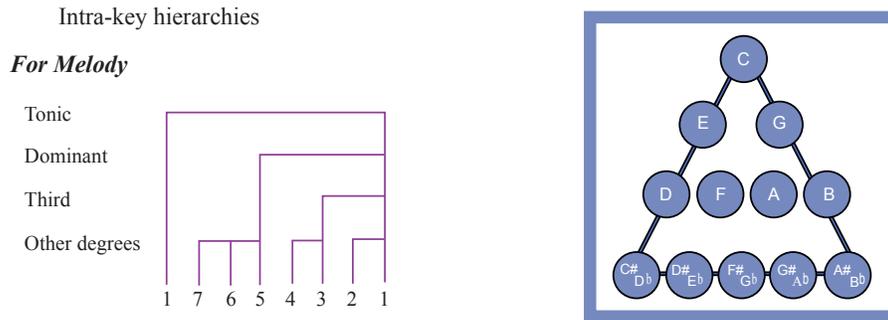
Melodies can be composed from whole note sequences directly, by stringing together smaller segments of melodic phrases or patterns or by first choosing chords and chord progressions and deriving a melodic sequence from them.

Both melody and harmony involve tonality -- a particular set of pitches and pitch relations. Tonality is the relation of pitched auditory events to a reference pitch (the tonic) that has been recently established in auditory memory. The process of establishing a tonic or tonal center or musical key is called tonality induction. The first and last notes often are the tonic or closely related to it. Often the tonic is the most frequently played note or the note with the longest durations, although the tonic need not necessarily be played to be established if other, related notes (that have many harmonics and subharmonics that overlap with those of the tonic) imply it. We viewed the demonstration of the Music Animation Machine "tonality compass" in which a running representation of predominant pitches depicts the music's tonal "center of gravity" as it changes.

Perception of the tonic can be influenced by melodic and harmonic context through the course of a musical piece. There are key-finding algorithms that have been developed, but these can make errors in the sense that their predictions of tonal center or current key do not always match those of human listeners.

Tonal hierarchies. (Krumhansl pyramid) Tonality induction implies that there is a tonal center (the tonic) and notes that are successively further from this center. Moving outwards these are

the fifth, the third, then other notes in the diatonic scale, then other notes in the chromatic scale. This tonal hierarchy is a reflection of distance in perceptual pitch space.



Melodic tension and relaxation. Often melodies begin and end with the tonic and in between there are excursions away from and towards the tonal center. Excursions away from the tonic create tension (T) and those towards the tonal center create relaxation (R). Alternating tension and relaxation is part of the push-pull of tonal music.

For most of us, music pitch is entirely relative, yet despite this we recognize relative pitch ratios, musical intervals. Melodies are easily recognized if the pitch ratios/musical intervals are held constant but the absolute frequencies are all changed by multiplying them by a constant factor (or shifting all notes up by a given number of semitones). This is called transpositional invariance.

To some degree a melody can also be recognized (albeit less reliably) if the ups and downs of pitch changes are kept the same, but the sizes of the steps (the musical intervals) are distorted. The up-down pattern of a melody is called its contour, and there is some discussion, debate, and (frankly) confusion over the relative contributions of musical interval patterns vs. contour in melody recognition.

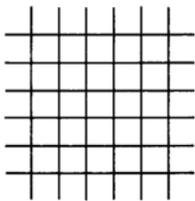


FIGURE 2.12. REPOSE



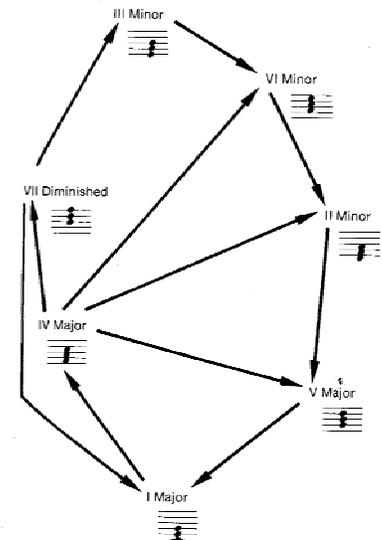
FIGURE 2.13. STRESS

Figures from *A Primer of Visual Literacy* by Donis A. Dondis.

Cambridge, Mass., MIT Press [1973]. Used with permission.

another element is misplaced or omitted. A weak organization on the other hand, has arbitrary parts that do not interact in any orderly way. Strong "tonal" melodies composed of notes in the diatonic scale are more easily recognized than weak "atonal" ones composed of notes randomly taken from the chromatic scale. Krumhansl's melodic probe-tone studies showed that tonal passages created stronger sets of tonal expectations (whether a test note "fit in" with a melodic context) than atonal melodies. [Part of the whole point of 20th century atonal music was to avoid creation of tonal centers so that other kinds of musical organizing principles could be explored.]

We discussed the Gestaltist concept of strong vs. weak organization (closure). A strong organization is one in which the parts or relations reinforce each other in a manner that yields strong predictive order. One readily notices if one or another element is



Courtesy of MIT Press. Used with permission.

Source: Handel, S. *Listening: An Introduction to*

the Perception of Auditory Events. MIT Press, 1989.

Melodies play out in time with notes of durations ranging from 100 ms to about 2 seconds. If the notes are too short (< 100 ms), they fuse together into glides and the melodic line is lost. If the notes are too long (> 2 sec), the notes do not cohere together into a unified pattern. Both melodic and rhythmic chunking exist within this same temporal event window, which implies that the same short term auditory memory processes that form a pattern out of successions of events may be involved in both.

Image removed due to copyright restrictions.

Major and minor scales, with each degree shown as the root of its triad.

See Ex. 16 in Piston, Walter. *Harmony*.

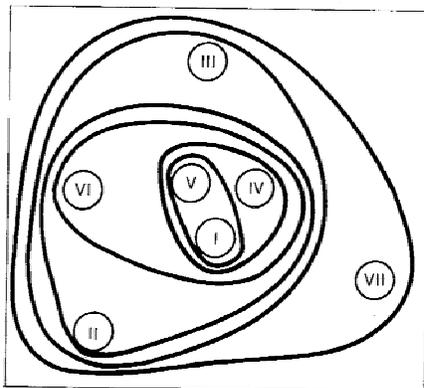
Harmony in the vertical dimension involves relations between concurrent pitches. Much of western music is based on 3-note chords ("triads") in which there is the root, the lowest note, plus the third note in the scale, plus the fifth note in the scale. The major triad in the key of C is C-E-G. We discussed scale degrees of chords, in Roman numeral notation, I, II, III, IV, V, VI, VII. Sometimes major triads are notated in uppercase Roman numbers, while minor triads are notated in lowercase ones, e.g. I, ii, iii, IV, V, vi, vii.

A major triad is highly effective in establishing a tonic, and often a musical piece will begin and end with a major triad. Much of tonal music is based on chord progressions within a single key. We listened to a (primitive) 3-chord song Wild Thing and watched the chord progressions in the Music Animation Machine LATTICE representation for visualizing triads. The chordal arc of a piece often goes from the major triad I to less stable chords and then back to the triad. Different musical styles have different chord progressions, e.g. 50's progression I-V-vi-IV or jazz II-V-I.

As with pitches, there is a hierarchy of relatedness between chords that is anchored in the I chord of the key (either the major or minor triad). This ordering of chord perceptual proximity goes I > V > IV > VI > II > III > VII. Each movement outward from the I chord builds tension, while each movement back towards the I chord provides relaxation. Thus a I-IV-V-II-VI-IV-V-I chord progression produces a T-R-T-R-R-R sequence of tension and relaxation.

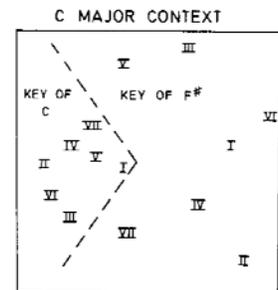


Courtesy of Stephen Malinowski. Used with permission.



is a distance map between keys.

Lastly there are key modulations in which the tonic is changed (new ones are established through the course of the piece). This changes the whole tonal context. We listened to We Can Work It Out, which I transposed into the key of C and visualized the chord sequences in the MAM lattice program. The song starts out in C major, modulates in the middle to A minor, and then returns back to C major (it goes through this major-minor-major sequence twice). The Circle of Fifths



Source: Fig. 1 in Bharucha, J. and C. L. Krumhansl.

"The Representation of Harmonic Structure in Music: Hierarchies of Stability as a Function of Context." *Cognition* 13, no. 1 (January 1983): 63-102.

Courtesy Elsevier, Inc., <http://www.sciencedirect.com>. Used with permission.

Source: Krumhansl, C., J. J. Bharucha, and E. J. Kessler. "Perceived Harmonic Structure of Chords in Three Related Musical Keys." *J Exp Psychol Hum Percept Perform* 8, no. 1 (Feb 1982): 24-36. Courtesy of American Psychological Association.

Carol Krumhansl carried out systematic probe tone experiments using notes, melodies, and chords as contexts to probe the universality and properties of tonality induction. The immediate tonal context (of the sounds heard in the last few seconds) sets up a tonal space of similarity (and tension) relations that does not require learning of particular culture-bound schemas. As David Huron says in his review of the Krumhansl book (posted on BB), we are good musical tourists. However, additional, culturally-conditioned expectations do come into play when one is listening to music of one's own culture.

In summary, there are three similarity hierarchies, for tones in melodies, for chords in chord progressions, and for keys in key modulations. In each domain in Western tonal music, there is typically an excursion from an established "center" to more unstable realms and then eventually back to the center.

What you should know:

Tonality is based on pitch relations.

What is the tonic?

What is tonality induction?

How is the tonic established?

What is a melody?

What is melodic transposition?

Intervals vs. contour

What is a chord?

What is a chord progression?

How are chord progressions related to harmonic tension and relaxation?

What is a key?

What is a key modulation?

How are modulations related to harmonic tension and relaxation?

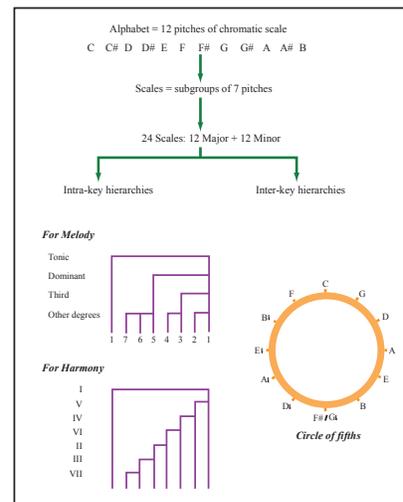


Figure by MIT OpenCourseWare.

Rhythm

Rhythm in its broadest sense involves perceived patterns of sonic events in time.

Where melody involves the pitch relations between sequences of sonic events, rhythm involves the relative timings of events.

There are two major aspects of rhythm perception:

- 1) the grouping of events into chunks (rhythmic pattern induction) and
- 2) the formation of a metrical temporal grid underlying events (metrical induction)

Rhythmic pattern induction

Every repeating pattern of events creates an expectancy of its continuation.

Further, there is grouping or "chunking" of the repeated pattern; the repeated pattern becomes an object.

We illustrated this with Gestaltist figures that provide visual analogs and by creating arbitrary repeating sequences of sounds in our synthesizer program.

After a one or two repetitions, one forms a strong expectation of the continuation of the pattern.

For a sequence of identical notes, groupings can be created by changes in any perceptual attribute: loudness, timbre, pitch, duration, relative timing of onsets.

There is a parallelism between rhythmic grouping and melodic grouping, and the two grouping mechanisms can reinforce each other to form strong phrase structures or compete to mutually weaken perceptual grouping. The temporal window for events that cohere into rhythmic patterns and melodies are similar -- events must be at least 50-100 ms apart (or they will run together) and no more than 2-3 seconds apart (or successive events don't interact to form a pattern). This time window reflects the properties of auditory short term memory.

Repetition of a pattern is the strongest, most direct means of establishing its expectation.

Rhythm is hierarchical in that time intervals can be subdivided into shorter durations (the rhythmic equivalent of ornamental notes) without destroying higher level temporal relations (deep structure vs. surface structure).

We looked at different notations for rhythm, including standard musical notation. The necklace notation is useful for depicting repeating patterns -- we heard several examples of traditional African rhythms and observed their necklace notations.

Memory processes generate musical context, which is a set of expectations that can be confirmed or violated. The auditory system is constantly building up a representation of sound patterns that is compared with patterns of incoming auditory events. When the patterns are consistent with the current representation, an auditory image is reinforced; when incoming patterns diverge from expectations, then these patterns or events are amplified and new expectations are created from the violations.

I spoke briefly of my work on recurrent timing nets, which are neural nets that hold temporal patterns in an array of delay loops. When a pattern repeats, it builds up in the delay loop whose recurrence time equals the duration of the pattern.

There is a parallel between pitch and rhythm, despite their different temporal scales. A repeating waveform pattern of duration 0.5-30 milliseconds (i.e. its fundamental period) is heard as a pitch; a repeating temporal pattern of events of duration 100 milliseconds-many seconds is heard as a rhythmic chunk whose duration is the fundamental period of the repeating pattern.

Similar kinds of processing through such timing nets may subserve both pitch and rhythmic processing. This hypothesis remains to be tested neurally.

Meter

When we listen to a series of events in time, if they are regularly occurring, we build up an expectation of an underlying temporal grid.

The basic unit of time in such a temporal grid is the pulse, beat, or tactus (often these terms are used interchangeably), and the events that occur are also called beats. The tempo of a piece of music is the beat rate, given in beats per minute.

Accents are salient contrasts. Accented events are events that are more salient to us -- they stand out in our experience. Accents can be created by several means -- a change in loudness, pitch, note duration, timbre (e.g. sharpness of attack), preceding duration of silence, or timing re: expectation (expressive timing) can emphasize/accent a note, as can expectations created by grouping processes.

Typically there is a pattern of accented and unaccented beats, called a pulse-group. A repetitive, regularly accented pulse-group is called a meter.

Different meters consist of different patterns of accented and unaccented beats, e.g.

ONE two, ONE two, ONE two (duple meter)

ONE two three, ONE two three (triple meter)

ONE two three four, ONE two three four (quadruple meter)

Metrical induction

When we hear a metrical pattern, we develop strong expectations of its continuation. If a physical beat is missing, we nevertheless have a feeling of the existence of an implied beat when the beat was expected. This implied beat is seen in electrical potentials (event-related potentials) in both adults and in newborn babies.

Expressive timing is the intentional creation of deviations from the expected timing of musical events (either from rhythmic pattern grouping or vis-a-vis the metrical grid). Note onsets are sped up or delayed to emphasize them in unexpected ways.

Optional Material

We did not discuss time signature notations in class, but in a time signature, such as 4/4 time, the upper number indicates the number of beats to the bar (measure), while the lower number indicates the note duration that constitutes one beat (4 = a quarter note is one beat, 8 = an eighth note is one beat). Bars in music notation indicate measures, the temporal boundaries of the pulse-groups, the duration of the repeating underlying pattern of accented and unaccented notes. A conductor indicates the beginning of a bar by an upward motion of his/her baton, and hence the first beat of a measure is called the "upbeat" and successive, unaccented beats, especially the one preceding the beginning of a new measure, are called "downbeats". Accented even beats (e.g. 1-

2-3-4, 1-2-3-4) instead of the more common odd beats is called a "backbeat", often used in rhythm & blues and rock 'n roll. Syncopation accents beats that would not normally be accented (so a backbeat rhythm is a syncopated rhythm because the normal pattern of first and third beats being accented is violated).

What you should know

Rhythm involves perception of temporal patterns of events

Recurring patterns group into chunks that create expectations of future temporal occurrences of events (rhythmic pattern induction)

Rhythmic grouping occurs on the same timescale as melodic grouping.

We also infer a metrical grid that involves a regular set of timepoints (pulse, tatum) and a regular pattern of accented/unaccented events (meter). (Metrical induction)

Expectations generated from rhythmic grouping and metrical induction processes can be manipulated for tension-relaxation effect.

Even newborns have basic expectations regarding the timing of events and the continuation of regular rhythmic patterns (meter induction).

Expectancy, Meaning, Emotion, and Pleasure

Here we tackle emotion and meaning in music.

What is meaning? What makes music meaningful to us is that it can induce or modulate our psychological states. [Generally speaking, this is its purpose]. Music that doesn't move us in one way or another is not meaningful to us.

The "meaning" of a piece of music for a given listener is its effects on that person's psychological state:

- Perceptual-cognitive states
- Mood & emotional states
- Social psychological states

While meaning in communicative, linguistic contexts involves the relations of symbolic tokens to the world at large (e.g. "that truck" – the truck you see before you), most musical meaning does not involve explicit reference to perceived objects or events in the external world (although as we saw, there are circumstances where it can suggest particular interpretations).

Psychological functions of music: why we do it

- Perceptual-cognitive interest (formalism)
- Mood control & emotional expression (expressionism)

Sources of musical meaning

Intrinsic music expectations (tension & relaxation)

Internal associations: body rhythms, patterns

External environmental objects, sounds, rhythms

External musical associations, expectations (e.g. dirge)

Lyrics and their semantics

Linkages w. memories

What cues convey emotional meaning in music?

Tempo, rhythm, dynamics, expressive timing

Melody, harmony, major-minor key

What physiological processes are involved?

Chills, pleasure, fear, reward, expectation violations

Music, Expectation and Meaning

Leonard Meyer in his book *Emotion and meaning in music* (1956) argued that music creates meaning through its creation of music-specific expectations and their violations. These lead to push-pulls of tension and relaxation, which create emotional effects (alongside cognitive engagements). This is the internalist view of meaning in music.

We looked at a study by Koelsch et al in which subjects were played expected and unexpected chord progressions ("cadences"). Event-related potentials show a "mismatch negativity" (MMN) at particular times after an unexpected event has occurred, and MMNs were observed when harmonic expectancies were violated (e.g. I-IV-II-V-II cadence vs. the typical I-IV-II-I cadence). Functional magnetic resonance imaging (fMRI) studies locate activity associated with the detection of these expectation violations of expectations in Broca's area, which is a region in the prefrontal cerebral cortex that is known to be involved in the language syntactic comprehension and production. Here we have an example in which musical patterns that have no obvious relation to the external world nevertheless generate neural response patterns that normally accompany expected sequences of events and their violations (surprise). Here music is conveying meaning that is internal to the expectations generated by its own structure (mediated through mechanisms of perception, cognition, and memory).

Similarly, Jamshed Bharucha came and talked to us about their study of musical tonality (key modulations) and frontal lobe activation patterns. They found that key changes produced dynamic activation patterns in the frontal lobe that are related to harmonic expectancies and violations (and tension-relaxation).

There are also examples, however, of music that mimics temporal patterns in the world at large (we played Mussorgsky's musical depiction of oxen from *Pictures at an Exhibition* as an example; Messaien's birds are another). Can music convey meaning that is related to our representations of the outside world? Yes, to some degree.

We also saw that music can prime particular words and concepts. Another study by Koelsch et al looked at whether musical passages can prime (suggest) particular words or their related concept clusters (we listened to many of these in class). The effect is striking – that music can crudely suggest semantic conceptual meanings (river vs. needle; devotion vs. mischievous, sun vs. basement).

The fact that music also activates brain regions that are involved in language comprehension and production may mean that both music and language utilize the same domain-general cognitive

faculties. Alternately, one might conclude that this is evidence for music being a by-product of our capacity for language. This question is unresolved at present, but should be better understood in the next few decades.

Music & Emotion

Music may also engage the emotions by means of mimicking internal body rhythms, such as heart rate, breathing, walking, running, leaping. We did not discuss this in class, but Manfred Clynes had a theory of "sentic" in which music drives our nervous systems in temporal patterns that are not unlike those involved in neural activity underlying emotions. If the central neural codes are temporal codes, as I believe may be a possibility, then the direct effects that music has on us are not so mysterious – music is impressing on our nervous systems patterns that would normally be signals for particular emotional states. There is no need then to postulate that music derives its emotive effects from speech-related modulations (e.g. stress, pitch, tempo). This is just a hypothesis, and we are nowhere close to understanding the central neural codes that operate in the cerebral cortex and the limbic system. Again, we will learn more in the coming decades.

Emotion has three aspects

- A. physiological arousal, (or neurophysiological processes)
- B. behavioral expression (e.g. facial expressions), and
- C. conscious experience, the subjective feeling of an emotion.

Conceptions of emotions

- Reflections of general internal mental states
- Predispositions for orientation, action
- Reflections of general body states (Wm James)
- Can be modulated by
 - events (stimuli)
 - memories (experience, prior conditioning)
 - pharmacological agents & electrical stimulation
 - body states

We looked at a two-dimensional typology of emotions (arousal vs. emotional valence of negative vs. positive) and played some musical examples from the various shades of emotional state.

Mood vs. emotion – mood is a basic emotional background or baseline state, whereas emotion involves a state that is more transient and related to recent events/situations

Some musical factors that influence emotion:

Low degree of arousal

e.g. "relaxation music", shopping music

Low intensity, slow-moderate tempo, flat dynamics, conventional/unsurprising melodic & harmonic structure; insipid lyrics

High degree of arousal, e.g. march, gospel, anthems, calls to action

High intensity, fast, brisk, upbeat tempo, roller-coaster dynamic, rhythmic, melodic and harmonic modulations; unexpected, unpredictable events (e.g. Rite of Spring); strident, forceful rhythms

rousing lyrics that stir emotions; shouting

Happiness/joy

Quickening tempo; accelerando; increasing dynamics; crescendo

Rising melodies, resolution of tension; major key (Western music)

Sadness/quiet apprehension

Slowing tempo; ritardando; attenuating dynamics, diminuendo

Predictable rhythmic patterns, rhythmic hesitancy, pregnant pauses

Falling melodies (e.g. Risset glissando rising vs. falling - bummer!), presence of dissonant, unsettling chords

Suspense/terror

Increasing arousal; harmonic and rhythmic dissonance; unexpected jarring events (Night on a Bald Mountain, Hitchcock soundtrack)

Music and Pleasure

Finally music is itself a source of pleasure.

Keoelsch et al found that unpleasant music activates limbic structures that mediate the emotion of fear (the amygdala), and that pleasant music activates limbic structures that mediate pleasure (dopamine neuron populations in the anterior superior insula). Menon and Levitin (2005) also found activation of dopamine neuron populations associated with pleasure and reward in the nucleus accumbens and ventral tegmental area (VTA). In class we listened to a radio interview by (Terry Gross, Jonah Lehrer, Fresh Air) on dopamine, pleasure, temporal prediction, and gambling addiction.

What you should know

Music can generate strong expectancies

Expectancies create tension-relaxation dynamics

Tension-relaxation dynamics modulate emotions

There is no “music center” in the brain that is exclusively dedicated to music. Music activates circuits also used for other things.

Music can create semantic expectancies that interact with lexical semantics

Many structural elements of music evoke emotional effects: tempo, dynamics, melodic, harmonic & rhythmic expectancies (know generally what these are)

Music engages neural circuits related to anticipation, prediction, and reward

Music engages limbic system circuits related to pleasure, unpleasantness, and fear

Musical Preferences

There is considerably less research on musical preferences than on emotion and meaning in music. We deal here with general musical preferences generally shared across populations of people (e.g. US population) and with the interaction of personality and musical preference.

One might think that there would be a great deal of research on music preference that is carried out by the music industry, if only to better target and segment their markets. For better or worse, we have not been able to find much in the way of surveys of the general population.

General Population Preferences

One study we did find is a semi-tongue-in-check exercise (one might think of it as conceptual art) by sound artists Dave Soldier and Komar & Melamid called *The People's Choice* in which they polled several thousand people on music preferences and composed two pieces of music using the parameters that were rated most desirable (the most wanted song) and least desirable (the most unwanted song). We played samples of each of these in class.

"The most favored ensemble, determined from a rating by participants of their favorite instruments in combination, comprises a moderately sized group (three to ten instruments) consisting of guitar, piano, saxophone, bass, drums, violin, cello, synthesizer, with low male and female vocals singing in rock/r&b style. The favorite lyrics narrate a love story, and the favorite listening circumstance is at home. The only feature in lyric subjects that occurs in both most wanted and unwanted categories is "intellectual stimulation." Most participants desire music of moderate duration (approximately 5 minutes), moderate pitch range, moderate tempo, and moderate to loud volume, and display a profound dislike of the alternatives."

"The most unwanted music is over 25 minutes long, veers wildly between loud and quiet sections, between fast and slow tempos, and features timbres of extremely high and low pitch, with each dichotomy presented in abrupt transition. The most unwanted orchestra was determined to be large, and features the accordion and bagpipe (which tie at 13% as the most unwanted instrument), banjo, flute, tuba, harp, organ, synthesizer (the only instrument that appears in both the most wanted and most unwanted ensembles). An operatic soprano raps and sings atonal music, advertising jingles, political slogans, and "elevator" music, and a children's choir sings jingles and holiday songs. The most unwanted subjects for lyrics are cowboys and holidays, and the most unwanted listening circumstances are involuntary exposure to commercials and elevator music."

Individual Preferences

Obviously, there is wide variation in the musical preferences of individuals. These can be due to the particularities of personality, one's uses for music, or of subculture.

We looked at several different theories/taxonomies of personality:

Temperament (biological predispositions)

Psychodynamic theories (e.g. Freud)

Humanistic theories (actualization)

 Maslow (hierarchy of needs)

 Rogers (self theory, self-worth)

Social cognitive theories (social learning, adaptation)

Trait-theories/typologies, psychometrics

Meyers-Brigg test

Eysenck 2-dimension (Extroversion/stability)

Catell's 16 factors

Big Five

The Big Five appear to be most commonly used in psychology. These dimensions are

- 1) Extroversion/introversion
- 2) Emotional stability/instability
- 3) Agreeableness/antagonism
- 4) Conscientiousness/undirectedness
- 5) Openness (curious, imaginative, independent)/non-openness (incurious, unimaginative, conforming)

There is one major study of personality and musical preference that we found: Renfrow & Gosling (2003), "The Do Re Mi's of Everyday Life: The Structure and Personality Correlates of Music Preferences." They used the Big Five dimensions to characterize personality tendencies and grouped musical genres into four types of music preferences. These were

- 1) Reflective and complex (blues, jazz, classical, folk)
- 2) Intense & rebellious (rock, alternative, heavy metal)
- 3) Upbeat & conventional (country, sound tracks, religious, pop)
- 4) Energetic & rhythmic (Rap/hiphop, Soul/funk, Electronica/dance)

They found some (modest) correlations between personality type and musical preference:

Subjects with high openness scores preferred reflective & complex music ($r \sim 0.4$) and intense & rebellious music ($r \sim 0.2$), extroverts tended to prefer upbeat & conventional ($r \sim 0.2$) and energetic & rhythmic categories ($r \sim 0.2$), while those with high agreeableness and conscientiousness scores tended to prefer upbeat & conventional music ($r \sim 0.2$). A correlation of $r = 0.4$ means that the personality score explains 16% of the variation between subject music preferences, whereas $r = 0.2$ explains 4%. See the lecture PDF and/or the original papers (BB) for more detail.

They concluded that personality, self-views, and cognitive abilities could all have roles to play in the formation and maintenance of musical preferences. They also believe that one's musical environment can influence one's personality.

What you should know

Preferences can be highly individualistic

Sociocultural factors

A good deal of variation may be due to different psychological uses of music -- what one uses music for

But this too may be a function of personality

Different personality types (Big Five categories) have weak tendencies to prefer different kinds of music (in terms of 4 music-preference dimensions)

Developmental Psychology of Music

This is an all-too-brief overview of the developmental psychology of music.

General issues

Origins of perceptual abilities and musical production

Innate vs. acquired capabilities (nature vs. nurture)

Is music a product of our ability to learn?

Is music a product of cultural transmission (our social nature)?

Modes of acquisition

- evolutionary adaptation (specific adaptation)

- ontogenetic unfolding of genetic programs

- ontogenetic learning/self-organization

- use of basic general-purpose perceptual-cognitive faculties

Developmental studies

- Infant perception (Trehub)

- Development of cognitive schemas (Bamberger/Piaget)

Implications

Sandra Trehub's discussion in the book *The Origins of Music*

1) Arguments for a strong role for nurture

children exhibit better perception and retention with age

adults & children show better memory for melodies structured in conventional ways

formal musical training is assoc w enhanced perception and retention

2) Arguments for a strong role for innate auditory mechanisms

skills of trained and untrained musical listeners more similar than different

sensitivity to musical distinctions manifest themselves very early on

What is unclear is whether similarities stem from processing dispositions common to all humans or from long-term exposure to similar kinds of music (hence infant studies)

Infant studies tell us whether musical capabilities are mostly innate or acquired by developmental processes and/or learning

Trehub's Infant Studies (6-10 months old)

Infant resolution of pitch & timing adequate for musically-meaningful distinctions in any culture (gap detection, pitch discrimination)

Melodic invariance under transposition and tempo

Small changes can be tolerated as long as contour is preserved

Contour sensitivity comes prior to interval-based structure

Infants more precise in perceiving diatonic melodies (conforming to major & minor scales); detect pitch changes a semitone or less even when melodic contour is unchanged

Discriminate between consonant, dissonant intervals (fifth vs. tritone)

Listen longer to consonant intervals (2- and 6-month olds); signs of distress when dissonant intervals are introduced

Trehub's conclusions: there are significant processing predispositions for musical structure ("gifts of nature rather than products of culture")

Although infants do respond differentially to sounds heard in the womb (mother's voice) prenatal exposure models unlikely because sensitivity to culture-specific aspects emerges at 5-7 years of age

We looked at a recent (2009) study by Winkler et al (PNAS) that used event-related potentials to determine if newborn infants expect missing beats (metrical induction, beat induction). They found that newborns "develop expectation for the onset of rhythmic cycles (the downbeat), even when it is not marked by stress of other distinguishing spectral features. Omitting the downbeat elicits brain activity associated with violating sensory expectations. Thus, our results strongly support the view that beat perception is innate."

There were other papers on infants using movement to inform rhythm perception. Finally, we discussed special-purpose modules vs. domain general faculties.

What you should know

Infants perceive basic aspects of tonality (pitch) & rhythm much the same way as adults (Trehub & Hannon, 2006)

They recognize mistuned harmonics, distinguish consonant-dissonant musical intervals, transpose melodies, and detect key modulations

Grouping processes appear to be similar to adults

At birth they have beat induction -- they have expectancies for missing beats.

There is debate about whether music is processed by domain-specific modules (Peretz) or whether music draws on general purpose mechanisms (Trehub, myself) that are common to speech, language, and other perceptual & cognitive functions.

These findings call into question theories of music acquisition that depend heavily on associative learning.

Comparative and Evolutionary Psychology of Music

We come back to the why questions – why does music have its effects on us?

Are there particular evolutionary adaptations that predispose us to like music (e.g. not unlike how some theorists think about genetic predispositions for language)?

Or have we found a means by which music can drive pre-existing brain circuits that allow us to control our own emotions and derive pleasure (e.g. more like alcohol, sports, video games)?

Universality of music (among people, among animals)

(There are amusic people -- Darwin was tone-deaf, although he liked music)

Specificity of perceptual, cognitive, and hedonic brain mechanisms for music

How unique are human beings?

Are specialized adaptations for speech, language, and music necessary?

If so, what were the selective pressures and phenotypic Δ 's that brought them about?

If not, what are the common faculties that music engages?

Comparative psychology of music studies music perception, cognition, and production across animals: Musical perception vs. musical preference is an important distinction.

Musical perception

Melody recognition, transposition

Rhythm recognition

Musical preference

Do animals prefer music to other sounds?

Do animals make music for pleasure?

Can some animal vocalizations be considered musical rather than or in addition to being communicative? Under what criteria?

Many animals make complex vocal calls – some are comparable to simple music in complexity (e.g. whale songs, some bird calls).

A number of animals (such as the lyre bird video that we saw) are capable of vocal mimicry – they can imitate sounds that they hear and string many sounds together.

Animals in captivity (such as Snoball the dancing cockatoo) can synchronize their movements to music, a capacity that was formerly thought to be specific to humans.

Animals in captivity (such as the Thai Elephant Orchestra) appear to enjoy making music (banging on instruments), even if it is unclear what they are hearing.

In the wild small monkeys were found to prefer lullabies to tunes with faster tempos (McDermott & Hauser). In the laboratory they observed the monkeys to have no preference for consonant vs. dissonant tone combinations.

Evolutionary Psychology

Evolutionary psychology embraces the notion that the structures and functions of brains (and minds), like those of the rest of the organism, are sculpted/determined by the demands of survival and reproduction (natural selection).

Darwinian evolution: random variation + selection

("Try everything, keep what is good" Thessalonians)

Convergent evolution vs. common lineage

Selective pressures for:

general purpose solutions (adaptability: env. variability high)

special purpose solutions (adaptedness: variability low, high efficiency required, "dedicated structures, specialized fns")

Constraints on evolution

Rate of genetic change (generational time, diffusion)

Developmental constraints (Galton's polyhedron (Gould), not everything is amenable to immediate construction, e.g. wheels)

In general, the more examples we find of animal music perception and preference, the less appealing are evolutionary psychology explanations that involve selective pressures that were specific to human evolution that resulted in specific genetic mutations that produce music-specific neural capacities. Convergent evolution is still possible in which different classes of animals develop similar adaptations for their environments (e.g. streamlined body shape for ocean-going mammals, birds, reptiles (ichthyosaurs)).

Evolutionary Psychology and Functions of Music

The problem: there is no obvious function of music that explains the major psychological reasons why we listen to or produce it:

Perceptual-cognitive interest

Parasitic on speech & language?

Mood control & emotional expression

Social functions: group identity, cohesion, ritual

Social selection functions

Mating theories

One answer is that every structure or behavior is not necessarily the product of a specific adaptation to a specific environmental challenge/selective pressure.

In many ecological contexts, production of salient sounds would be obviously maladaptive for individuals.

We also need to keep in mind that nonproduction of music does not mean that musical structure is not apprehended (e.g. young children, animals discriminating phonetic elements, etc.)

Music as Auditory Cheesecake

Discussion by Joseph Carroll (1998):

Knowledge might be adaptive, but the pleasure afforded by art, Pinker thinks, is merely a non-adaptive exploitation of adaptive sources of pleasure. The arts respond to "a biologically pointless challenge: figuring out how to get at the pleasure circuits of the brain and deliver little jolts of enjoyment without the inconvenience of wringing bona fide fitness increments from the harsh world" (p. 524). In this respect, literature and the other arts would work in the same way as alcohol, drugs, and rich deserts. Hence Pinker's suggestion that "music is auditory cheesecake, an exquisite confection crafted to tickle the sensitive spots of at least six of our mental faculties" (p. 534). The pleasure afforded by literature is of a similar kind:

"Now, if the intellectual faculties could identify the pleasure-giving patterns, purify them, and concentrate them, the brain could stimulate itself without the messiness of electrodes or drugs. It could give itself intense artificial doses of the sights and sounds and smells that ordinarily are given off by healthful environments. We enjoy strawberry cheesecake, but not because we evolved a taste for it. We evolved circuits that gave us trickles of enjoyment from the sweet taste of ripe fruit, the creamy mouth feel of fats and oils from nuts and meat, and the coolness of fresh water. Cheesecake packs a sensual wallop unlike anything in the natural world because it is a brew of megadoses of agreeable stimuli which we concocted for the express purpose of pressing our pleasure buttons. Pornography is another pleasure technology. . . . [T]he arts are a third." (pp. 524-25), Pinker, *How the Mind Works*

My Perspective

The auditory cheesecake explanation is largely in the right direction (not based on particular adaptive, survival value of music but on its effects on the nervous system). But the explanation is incomplete because it does not explain in detail why it is that music has these effects on our

nervous systems. For cheesecake the answer is obvious, but for music it is much less obvious. Here is my explanation for why music has these effects.

Music perception makes use of generalized perceptual and cognitive capabilities for grouping, sequencing, iteration, and time prediction that subserve many complex behaviors we engage in (speech & language, sports, dance, music perception & production).

These facilities are more highly developed in humans, but many animals share the same basic mechanisms (whose rudiments evolved hundreds of millions of years ago)

Music exploits those faculties that are already present (the stimulus organizes the tissue, competition for neural info-processing resources/cortical territory).

Musical pleasure arises from temporal prediction & reward systems that are basic to all animals (akin to the pleasure of catching a ball). There are other associative sources of emotional meaning & pleasure that we have discussed (body rhythms, external events, etc.). Music is like video games in that it efficiently drives these systems.

Beyond this it may well be the case that the basic neural codes (the language of the brain) are themselves temporal pattern codes, and that auditory modality is a particularly efficient way of imposing particular time patterns of neural activity that weakly mimic natural processes. If this is the case, then brains are temporal correlation machines and it is no mystery that temporally structured stimuli can influence our internal states.

Music and Language (my perspective also)

Language has been characterized as an innate, inherited specialized faculty for rule-based syntactic processing

However, language may recruit generalized perceptual and cognitive faculties for grouping, sequencing, and flexibly associating auditory inputs & symbolic structures

Music and speech reception/language understanding may make use of similar kinds of pre-existing mechanisms for extracting "natural" structure from tonal and rhythmic patterns (prosody, melody, rhythm). Further some linguists hold that semantic structure drives parsing of sentences rather than syntactically-autonomous rules.

Speech & language may not require huge genetic and neural innovations, by being able to use pre-existing faculties for communicative purposes made relevant by social cooperation and organization. These faculties might be refined and expanded rather than created de novo in humans

Music likewise could utilize the same functionalities in similar ways, although this might explain how we are able to apprehend musical structure, it still does not explain why we do it (why it is pleasurable to us).

What you should know

Comparative psychology studies music perception, cognition, and production in other animals in the search for commonalities that illuminate why and how music has its effects on us.

Evolutionary psychology deals with possible mechanisms by which capacity for music might have evolved, in humans and potentially in other animals.

There are a number of examples of possible music-like productions by animals.

Many animals make complex vocal calls – some are comparable to simple music in complexity (e.g. whale songs, some bird calls).

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