Music, the brain and ecstasy
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1. From sound...

Human brains have far more sophisticated sound processing capabilities than other animals

The faintest sound that we can detect translates to the eardrum moving the width of a hydrogen atom

The pinnae amplify high freq by reflection and slightly amplify a range of other mid freqs by resonance.

The ear canal intensify mid freqs with resonance

The middle ear comprises ear drum, an the ossicles (Malleus, incus and stirrup) which are a impedance match between air and fluid. The also boost mid-freq. The muscles holding the ossicles also clamp down within 10-500ms to protect against loud noises and internal noises (voice, heart etc)

The inner ear is the cochlea which comprises 3 parallel chambers coiled 3.5 times. The pressure wave travels the length of the upper chamber causing the entire middle chamber to vibrate. The organ of corti is on the base of this second chamber and comprises groups of 3-4 outer hair cells and 1 inner hair cell. About 14000 receptor cells and 32000 nerve fibers. The cochlea also masks internal sounds and shapes the sensory input - filters out background noise.

Humans localize sound by timing and loudness differences between ears. Also the pinnae makes directional frequency changes. Range estimation is by differences in the sound such as loudness and frequency changes (loss of hi-freq). On the horizontal plane humans can detect 1deg differences up to 1kHz and 2deg above. In the vertical plane 4deg at low freq and much less well above.

The nerves departing the cochlear split 3 ways, 2 related to localization and the other freq components (clear ordered division between lo and hi freqs.

The olivary bodies compare signals from the two ears. The inferior colliculi do spacial mapping. The superior colliculi integrate sight and touch.

Low in the brain stem, neurons tend to fire throughout a tones duration. Closer to the cortex they fire intensely only during tone starts and stops.

There is also another diffuse ascending system which is not organized by freq. It responds relatively slowly and connects to cortex areas for attention, memory and learning.

2. ... to tone ...

A tone consists a primary frequency and a series of overtones at multiples of the fundamental. (the A below middle C has a freq of 110Hz, and frequency doubles from octave to octave)

So every musical note is in fact a chord but our brains register only the fundamental.

Slight deviations to lower tones are heard as a separate sound. Higher overtones crowd together in the forth octave and at much lower intensity, but they can muddy base tones noticeably as they are in our most sensitive range. High notes are poor in overtones because the strings cannot vibrate at such high frequencies.

Timbre is the uneven mix of the overtones in a note during the rise, middle and decay.

A formant is the resonance band of a particular instrument.

Humans do not finely distinguish loudness.

Reflections arriving within 50ms are interpreted as part of the original sound. This is not simply blurring because the human ear can

distinguish delays of 1ms between separate sounds.

A hall is said to be intimate when first reflections arrive within 20ms. There is a marked preference for reflections arriving from the side rather than overhead. Best seats are 20m from the stage and some-what off-center. Reverberations of the hall assist the brain in integrating earlier phrases of the music.

The nerves to the auditory cortex are arrange by frequency but there is a high degree of overlap.

Only a few neurons are specific to a specific frequency. Many more respond to changes in pitch or repeats.

The neurons in the primary cortex both strengthen particular features and inhibit other neurons.

We deafen quickly to constant sound. Psychologists have identified that the brain is primarily interested in change.

The secondary auditory cortex is partly organized by frequency and partly mysteriously The brain consumes about 22% of the bodies energy and gram for gram is only behind the heart and kidneys.

The primary cortex focuses on individual sounds while the secondary focuses on the relation between multiple sounds. The right brain auditory cortex focuses on relations between simultaneous sounds particularly tone rich in overtones and the highly harmonic vowel sounds of language.

3. ... to melody ...

A melody is a sequence of notes of varying duration and accentuation.

Humans do not recognize precise tones but rather category's of tones. Human can distinguish the difference between some 1300 pitches within the musical range but cannot maintain 1300 categories. "A brain understands the world by reducing perceptions to categories, and it recalls past experience by reconstructing it from categorical memory."

The Octave is a basic common structure in music. It is a simple doubling of frequency used to break up pitch space (ratio 2:1).

Other small integer ratios of frequencies also sound pleasing.

Each octave is typically broken up into a scale of notes. There are a variety of way of doing this - all are compromises. Small integer ratios of the fundamental freq sound best (due to harmonics) but when a piece of music is transposed to a higher key (say up 1 step) then the harmony is disrupted because the relations between notes are changed. An alternative (used in western music - tempered scale) is to divide the octave up such that each note is a constant ratio of the immediately preceding note (which allows music to be played in any key without destroying the harmony). Now if the octave is broken into 12 notes then many of these notes fall close to small integer ratios of the fundamental and sound pleasing as a result. (5 and 19 also work well).

The contour is the most basic and important characteristic of a melody. Discrete notes form the contour and are far more common than slides.

Harmony is the next most important characteristic. "... the relations we hear in a melody are not primarily the note-to-note relations of contour, but rather the relations between melody notes and the prevailing center.

Rhythm is the next most important.

Melody is recognized in the right auditory cortex. But the left becomes more prominent in trained musicians.

Melodies generally conform to the following rules....

4. ... To harmony ...

5. ... to rhythm ...

There are two different types of rhythm: meter and phrasing. Meter is the regular beat enhanced by syncopation and accents (instrumental rhythm) while phrasing is the more natural type of grouping of elements (vocal rhythm). "broadly speaking, meter organizes musical time on the small scale while phrasing organizes musical time on the large scale."

Rhythm exists in music to assist the brain in chunking it into manageable portions. Patterns are then sought in these often hierarchical chunks.

At the core of meter is pulse - the unceasing clock beat. Pulse keeps unchanging phenomenon alive by renewing attention.

Meter hinges on prime numbers as the brain cannot divide them easily into smaller chunks. Even a meter of 5 is difficult, 7 is very difficult. Even harder is poly-rhythm (poly-meter) where multiple rhythms exist concurrently. Syncopation is a ghost of a poly-rhythm where of beats are accentuated sufficiently regularly for them to be anticipated above and beyond the regular metrical pattern.

Phrasing breaks music up into hierarchical chunks. Consider the Pink Panther theme, very little obvious meter, a lot of phrasing. Spoken language is broken up into phrases, commas, sentences, paragraphs etc. It is a type of rhythm because it is devoted to mapping the flow of time. The mechanism or markers of phrasing is the completion of a musical idea - often a harmony but also pitch, pauses and loudness markers.

Phrasing is invisible to those without the necessary perceptual skill.

Form refers to very large scale phrasing.

Neuropsychologists define time as the perceptual present which has a finite measurable extent based on how fast neurons fire. Est 0.5 to 10 sec. Longer perception of music is enabled by memory and anticipation which work with ideas and relationships.
We can only handle about 7±2 observations at once.

Perceptual present is a bite-full of conception, not a bite-full of time.

Temporal resolution. We need 1ms to register a sound, 2ms to register separation between sounds, 13ms to register pitch, 50ms for loudness, 100ms for timbre. We need about 18ms separation to know which sound came first!

Musical perception is very sensitive to tempo. It is not the beat rate, it is the rate of renewals of attention.

When musical notes are presented to fast they become texture and the brain abruptly switches to larger structures.

Even composers are inconsistent regarding the correct tempo of their own work.

"It's often said that rhythm is music's most "natural" aspect, that it comes to music from pulsations we find in our bodies. This is one of those observations that, like the flatness of the earth, is blatantly obvious and blatantly wrong."

The left hemisphere is dominant for rhythm but the capability is clearly distributed.

6. ... to composition ...

Main point is that all composers are different in a myriad of ways.

7. ... To performance ...

A musical savant has perfect pitch, fine

grained perception, strong aural imagery, and phenomenal musical memory all operated by rigid memory. Most are victims of infant autism - 1 in 10 of 7 in 100000. Only 100 prodigious musical savants like blind Tom have been identified. 6 of 7 male and 1 in 3 musical. Musical savants are usually blind.

The precise physical movement required by musical performances requires astonishing coordination of the body bolstered by detailed feedback at all levels..

The motor cortex prepares the specific physical actions but it is complex and integrated. There is no easy mapping between motor cortex and body parts or muscle groups. Movements are rarely single muscle actions but whole body movements. It is best described as mapping types of basic movements (but not sequences). However, individual motor neurons are most strongly tuned to the direction of movement and the preferred direction of movement change constantly!

The planning of performance is hard to isolate. The premotor cortex coordinates sequences of movements. The frontal lobes are accredited with advanced planning but damage affects personality and attention not movement. The basal ganglia gathers and redistributes info between other parts and has a role in initiating movement. The cerebellum has more neurons than the rest of the brain combined and coordinates the physical balance between movements. The cerebellum coordinates ballistic movements (too quick for feedback) speed over accuracy.

Feedback from muscles comes from millions of tiny spindles embedded in muscle fibers routed back to the somatosensory cortex (parallel to the motor cortex and just behind) This is very rich info but largely below consciousness. We can work or without it while we have vision. Our fingerprints are important to magnify touch sensation. Info from touch, sight and hearing are drawn together in the parietal cortex (just behind somatosensory). This is where the body map meets the world map.

While reading music, the eyes embrace an area about 25mm dia and move every 20th of a sec in a manner which reflects the structure of the music (anticipation is an important director)

Early exposure to music training make a significant difference - there are critical periods of development - the bridge between the two sides of the brain (the corpus callosum) are 15% higher in adults who started playing the piano before the age of 8 than otherwise.

Kinesthetic imagery is important to most musicians in learning and playing a piece from memory. It is also a structural form of memory rather than sequential. Virtuoso concentrate on practicing fragments rather than whole pieces.

Musicians tent to be androgynous and become more-so with time in the profession.

8. ... To listening ...

We do not only listen to music for pleasure, it vary from hearing thru listening and technology has made it much more pervasive.

Expectation coincides with episodic memory while anticipation coincides with semantic memory. The more daring the music the harder it is to anticipate.

Attention to music usually rests on the most critical features, the edges of musical objects such as melodies at the peaks and troughs and violations of metrical pattern. The memory models are built on these. Bass and treble lines bound music and as outer edges attract the most attention. The middle voices are often only filler except on harmonically complex music. Attention flicks between these “edge” elements to build models.

Untrained listeners can often not recall melodies without bringing the lyrics to mind. Perception of complex harmony is the rarest of listening skills. Allegiance to meter is fairly common, to phrasing less so.

Music is interesting when it goes just beyond

expectations.

People almost always prefer music with too little information content rather than too much and people tend to prefer increasingly complex music as they grow older.

People primarily use music for mood enhancement. We listen to it for its meaning. Peoples personal preferences regarding genre are generally guided by their peer group.

9. ... to understanding ...

Purpose and meaning are inseparable. Furthermore meaning requires context.

In verbal language there is both meaning (definition) and intonation (feeling)

There may be parallels between music and language (the more precise) based on the left hemisphere language area and corresponding mysterious right area. Phrasing has similarities. Language skills are almost universal while music skills are rarer. Generative grammar has been proposed for language (Chomsky) and music (Schenker) but they differ is structure and focus. Brain lateralization is a tendency rather than an absolute. Brain scans are static averages rather than dynamic flows. Damage to music skills due to physical brain damage is poorly researched. Ultimately parallels between music and language are tenuous.

Language tends to be externally focused which music tends to be internally feeling focused. The internal and external are structured differently with the external being more distinct and componetized. Internal is more turbulent and we have trouble describing turbulence in the external world with language.

10. ... To ecstasy.

People suffering from Parkinsons disease (the brain desires movement but the body freezes) can be relieved with music. Also other organic movements such as horse riding or watching someone walk can get things moving.

Three questions. How does music elicit emotion from us? How is it that music gives us pleasure? What is happening in our brains when music leads us to the threshold of ecstacy.

French archaeologists found that the caves with the most painting has the best acoustics.

Perhaps the expansion of the cerebellum enabled not only tools but sufficient intelligence, memory and symbolism to enable cooperation.

Damage to the right frontal lobe can leave people emotionally unresponsive. The frontal lobes also do planning, short-term memory and attention - all forms of restraint (respectively....staying the path, not moving on instantly to the next sensory input and focus on one of many inputs).

One view of emotion is that it is a special case of motivation. One where something is anticipated and any discrepancy in the actual outcome results in a positive or negative emotion (no neutral emotions)

Then music generates emotion by setting up anticipations and then either satisfies them with resolution or withholds the resolution even further for a larger resolution.

Musical expression is at odds with musical structure because each microscopic performance deviation tends to weaken subsequent anticipation and resolution. However no deviation results in a cold mechanical result.

There is intellectual music which has its attraction in patterns and emotional music with its attraction in resolving anticipation.

The concept of pleasure is difficult to define and it is rarely addressed in research. Pleasure appears to be about reaching equilibrium (pain is the deviation from equilibrium) This is confused by pleasure/pain delivered by reward/warning systems. But this

is still inadequate because it does not explain the pleasure of chess or discussing politics. A broader view considers motivational theories of pleasure which again focus on anticipation and satisfaction of that anticipation.

The promises, teases, retreats and final resolutions in music are similar to lovemaking. Simple anticipation and resolution makes for banal music

Music lends structure and beauty to negative emotion that makes it all worthwhile. It makes the undignified dignified but must be against the emotional background of the listener.

Ecstacy is more than extreme pleasure - its defining trait is immediacy. Music has more immediacy that the other senses despite its much smaller neural basis. The sound of fingernails on a chalk board affect the body in a way that no other sense does.

Music goes beyond a static visual to a mass moving structures and relationship which allows us to attain a greater grasp of the world.

Closing comments: Perhaps AI will be able to take music beyond where it is now. “It will be all but lethal if it does”