Musical Consonance & Dissonance: The Good, Bad and Beautifully Ugly

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What's Good?

Music has a peculiar relationship with concepts such as 'good', 'value' 'pleasure' and 'comfort'. We typically deem music as valuable if it gives us pleasure – it makes us feel good, so it is good. But even this basic idea is fraught with complexities. Some of the music we like, and particularly the music we *love* contains within it moments that are challenging, tense, uncomfortable, and even painful. Music that is merely pleasant does not hold our long-term interest or deep engagement, it's as if the profound in music has to be sometimes earned, even endured. What is instantly accessible might not bear repeated listening, while others might reveal their value over time – even years: There is often an acquired taste for the truly exquisite. Stranger still, listeners can acknowledge accomplishment, skill, and creativity in a piece of music or artist without personally enjoying it, its value is not linked to a direct pleasure. Alternatively, we may gain (a sometimes secret) joy from music that we think or are told is 'beneath' enjoyment – a so-called guilty pleasure. What we enjoy in music is also shaped by what we are exposed to, our culture's values, and also our personal histories. On the latter point, research shows a period of our younger lives (from early teens to early twenties) where many of our life-long favourite pieces of music are forged. This *reminiscence bump* tempts many people through the ages to assert that all the greatest music in history just so happened to occur in that narrow space and time. The 'kids these' days (be they in the 1980s, 1990s, 2000s or 1720s) are missing out on 'real music'.

So, if we can't rely completely on our initial impulses. How can we determine what is good in music? Records sales and public opinion share similar – or perhaps more extreme – biases. Perhaps critics, insider experts and gatekeepers can be useful. However – as collated entertainingly in Nicholas Slonimky's Lexicon of Musical Invective – even the artists and pieces now considered great were not uniformly appreciated at their time. Chopin's Concerto in E Minor was deemed "trivial and incoherent" (London Times, 1855), Beethoven's Eighth Symphony "eccentric without being amusing, and laborious without effect" (The Harmonicon, London 1827), and Berlioz "has no breath of inspiration and no spark of creative genius" (Boston Daily Advertiser 1874) and his *Symphonie Fantastique* a "dreary and cacophonous mess" (Boston Home Journal, 1890). There are countless such scathing criticisms no matter the degree of conservatism of the composite, nor admiration they would ultimately receive: Gershwin's music was "nauseous claptrap" (New York Telegram, 1928), Verdi "course and brutal" (New York, 1874), Rachmaninoff sounded "like a mournful banqueting on jam and honey" (1919) and Prokofiev was said to "camouflage his inability by pelting the hearer's ears with cacophonies" (World, 1918). Progressive composers were of course viciously panned: Stravinsky's *Rite of Spring* "has no relation to music at all as most of us understand the world" (Musical Times, 1913), Schoenberg "resembled the sounds an infant might make on the keyboard" (Washington Times-Herald, 1952) and Varèse's music sounded "like a terrible fire in one of the larger zoos" (1926), "unspeakably hideous" (1927) and "descriptive of an Irish potato under the influence of a powerful atomizer" (1933). Pop and rock artists are not immune from critical scorn, The Beatles were rejected from Decca because "guitar groups are on their way out, Mr. Epstein"; Rage Against the Machine guitarist Tom Morello had to stop engineers from 'correcting' his expressive behind-the-beat rhythms; Pink Floyd were "boring melodically, harmonically and lyrically", Joni Mitchell's "voice was malnourished", and Steve Vai (famed for his use of harmonics) was asked by a producer to "remove the squeaky notes" from his recordings. A 1969 review of *Led Zeppelin I* declared that "Jimmy

Page is [...] a very limited producer and a writer of weak, unimaginative songs". Such comments are not solely the utterances of clueless, narrow-minded or jealous critics: Tchaikovsky (who as a great composer, we might expect to recognise another) rated Brahms as "self-inflated mediocrity", "dried-up" and – rather poetically – a "giftless bastard" (1886).

In short, musical taste never has complete consensus, it ebbs and flows through history, exposure and in our personal histories. If there is any lesson then it might be to savour the music we currently enjoy but not take our (or anyone's) current taste and opinions too seriously. Rather we should listen widely and deeply to new music with open non-judgmental ears, and a curiosity about its diverse beauty.

We Shall Not Be Moved

In our first lecture, we looked at the acronym EVERBEAM (a succinct and accessible presentation of Juslin et al.'s BRECVEMA model) as an insight into how music moves us. This might also be used to help understand why we feel *unmoved* or actively repelled by a piece of music: For example, with respect to **E**motional Contagion, we may not be able to detect any emotion, dislike the conveyed emotion (anger or sentimentality etc) or even resent the manipulation. **V**isual Imagery, the music might evoke unwanted visual associations such as closeness, isolation, or squidginess. Similarly, in terms of **E**pisodic Memory and **E**valuative Conditioning - the music may serve as a reminder of a painful event, or unwanted associations (stylistic, political or historical). With respect to **R**hythmic Entrainment, we may resent a lack of a perceptible pulse, dislike the rhythm transmitted, or even feel patronised by an obligation to dance. We can find music too grating, not angular enough (**B**rain Stem Reflex), or too unpredictable and unfamiliar; or too generic and not surprising enough (**M**usical Expectancy). **A**esthetic Judgement is a complex mechanism, where although we can be moved by perceived skill, a foregrounding of virtuosity or musical knowledge (say in Jazz fusion), or devout fandom can alienate and put off individual listeners. At the same time, there can be a profound relatable charm in an imperfect but perfectly human performance. Few listeners, for example, would hear an improvement in autotuning Bob Dylan, or using multiple 'perfect' takes and multitrack overdubs of jazz performances. In short, while EVERBEAM provides us with a way of considering how music moves us, its relationship to musical taste is non-linear, complex and subjective.

Defining Dissonance

> *"[Consonance and Dissonance] have never been completely explained, and for a thousand years the definitions have varied. At first thirds were dissonant; later they became consonant. A distinction was made between perfect and imperfect consonances. The wide use of seventh-chords has made the major second and the minor seventh almost consonant to our ears. The situation of the fourth has never been cleared up. Theorists, bas- ing their reasoning on acoustical phenomena, have repeatedly come to conclusions wholly at variance with those of practical musicians"*

Paul Hindemith, The Craft of Musical Composition (1942)

Having peeked at the muddled world of musical value and taste, we can turn to our main topic, that of *consonance* and *dissonance*. These terms are extensively used but escape easy definition, and change in respect to cultural and historical context. As curated in James Tenney's *A History of Consonance and Dissonance,* to what these terms refer (either generally or specifically) is elusive and culturally malleable (see Hindemith's quote above). Dictionary definitions for consonance – as related to their etymology *consonare* "sounding together" – flock around terms such as the "agreement" and "compatibility" for consonance. In terms of music, the terms become a little more specific (although without consensus) and typically pitch-related, such as: "a pleasing combination of sounds" (OED), "an interval included in the major and minor triad and its inversions" (Webster's) or "stable intervals" (Gradus). Dissonance is – in opposition – discordant, unstable and requiring resolution. While consonance in music is often defined in terms of pleasantness, the opposite is not the case – particularly among musicians who see the opportunity – in fact necessity, of dissonance – in musical expression. Research shows that although pleasantness and consonance may be interlinked, even in infants and chimpanzees, with musical exposure and expertise, listeners gain pleasure from dissonance itself. This may feel counter-intuitive, but I find it a helpful (but limited) analogy of musical dissonance to be that of culinary taste. We can have degrees of flavouring and spiciness (lightly salted with a touch of chilli), and while some flavours are an acquired taste and repellent in excess, they are an essential part of the eating experience and enjoyment. So too with music, while there are objective measures of ‘disagreement’ of sounds, their link with pleasure and value is complex, cultural, dynamic, contextual and personal. We come to like – and even crave – coffee and jazz, while some have significant aversions to overcome with cruciferous vegetables and operatic head voices. Consonance for some may be pleasant, for others bland. Some musical objects defined as dissonances, like unresolved dominant 7 chords and syncopation (like the backbeat 2 and 4) are now entirely normative in blues-related music. Today’s experimentalism (9th chords, distorted guitars, dubstep bass, glitches and tape warbles…) become tomorrow’s advert music. This is not to say that there is a simple linear evolution (or devolution) into deeper dissonance, there are historic and traditional global practices (from Gesualdo’s false relations, the texture of Japanese *Noh theatre*, Chinese *Qin* ornaments, Xenakis’s algorithmically sourced orchestrations and Ives’ polytempo pieces) which would still challenge even an experienced contemporary ear.

The consonance and dissonance dichotomy is not an on-off affair and is even more than a dimmer switch. As we’ll see there are many ways that music can be variously ‘dissonant’ (by which we could mean rough, angular, challenging, statistically dense, tense, obfuscated etc) all in a range of simultaneous parameters: not just pitch but rhythm, timbre, tonality, centricity, polyphony, prediction etc. So the musical experience involves a multi-dimensional fabric of interacting dissonances, creating a flavour profile of bitterness, sweetness and sumptuous flavours. This description is not just metaphorical, music can induce ‘cross-modal’ physical reactions connected to our experience of touch, taste and smell. Indeed, the term ‘funk’ is derived from the Latin *fumigare* which means ‘to smoke’ and its associated smell. Zappa used the term ‘eyebrows’ as a reference to the evoked scowl in both the elicited response to the music and its inherent character. The more recent term ‘stank face’ is yet another expression for this long-documented musical experience which falls somewhere between deep visceral pleasure, and a sort of physical engagement, irritation or even repulsion: an ecstatic ‘pleasurable pain’ - the *beautifully ugly.* It relies on music’s unique ability to trigger a host of physical and emotional responses in the listener. These musical experiences rely on our response to 'dissonance' such as the ‘roughness’ of a sound, a scrunchy chord, an angular melody or a syncopated rhythm. But when coupled with the dopamine release from anticipation, satisfying predictions and bodily engagement, these can produce multi-sensory ‘cross-modal’ responses, from the chills, to a shaking head to a facial grimace. It’s as if music is so rich and flavoursome that it cannot be constrained by the sonic domain. it ‘bleeds’ into our other senses, not only do we hear it, but it is as if we can taste, touch and smell it also.

CD is a deeply complex and multi-dimensional field both in its study, and in terms of musical experience and creativity. How its various dimensions operate independently, and how they interact, has been considered for centuries but is still a burgeoning field. in their intuitive use by musicians and experience of the listeners.

Dimensions of Dissonance

Smooth Operators

In Western classical music, consonance and dissonance have been largely discussed in the vertical pitch domain. That is how agreeable, harmonic, sonorous pitches sound together. This is implied in Pythagorean, Bablylonian and other ancient forms of tuning where low integer ratios (e.g. halfway or two thirds of a string length – frequency ratios of 2/1 and 3/2, an octave and a fifth respectively) are considered consonant (see Lecture 3). More complex ratios (like 9/8, 16/15 or even irrational numbers) get progressively more dissonant. While the general connection of a mathematical simplicity and musical ‘purity’ is ancient, an attempt to actually quantify and compare these dissonances can be traced to the extraordinarily prolific and influential Swiss mathematician, physician, astronomer and logician Leonhard Euler (1707–1783). Among his many phenomenal insights, Euler was highly insightful and prescient in the field of music theory. He devised a formula to measure the dissonance of a musical interval based on its frequency ratio: The *Gradus Suavitatis* — ‘degree of suavity’ (‘pleasure’or ‘smoothness level’) — is a simple but elegant idea. It assigns values of dissonance in terms of *exponents*, a distance in an abstract pitch space. Any rational frequency ratio can be decomposed into a combination of prime numbers (e.g. 9/8 is (3x3)/(2x2x2)). In acoustical terms we can think of an interval as a journey along various harmonics, a series of ‘steps’ in this harmonic space. We start at a suavity of 1 and then each step is assigned an additional value. For example, jumping on the 2nd harmonic — ‘the octave line’ — costs 1 additional point of suavity for each step (3 octaves is 3 steps). The 3rd harmonic (an octave and a fifth) is 2 points for each step. The 5th harmonic, 4 points for each step and so on (each step of harmonic h costs (h-1) points). In short, the degree of suavity increases for how many times a prime harmonic is used, with the higher primes weighted more heavily.[1]

Two octaves (4/1) is a jump on the octave line (2 points) with an additional step (1 more point) = 3. To get to a pure fifth (3/2) we take one step along the 3rd harmonic (3 points) and an extra step on the octave line (+1): (3 + 1) = 4. 9/8 (a Pythagorean major 2nd) is 8 points and so on. There are many limitations to Euler's *Gradus* function, it is hand-wavey about perceptual boundaries, it is stepped rather than gradual, ignores timbre, enculturation, 'flavours' of dissonance and context, and throws up some strange results, including that φ (Phi – the 'golden' and 'irrational' ratio) wound be infinitely dissonant. Still, given its simplicity, Euler's formula (as well as similar contemporary approaches such as Benedetti numbers, Tenney height, measures by Parncutt & Hair, Johnson-Laird, Kang & Leong and my own *Scofield units*) align quite impressively with the real-word, subjective experience — such as the sensory dissonance curves of Lecture 4. In short objective measures like these are not perfect but align significantly in responses from adults, infants and even chimpanzees. It also correlates with compositional pedagogy and practice regarding common categorisations of consonant and dissonant intervals. Figure 1 shows how Euler's values produce a range of dissonances for the 12 chromatic notes in just-intonation.

	Interval	Ratio	Gs
Cons.	Unison	1/1	1
	Octave	2/1	2
	Perfect 5	3/2	4
	Perfect 4	4/3	5
	Major 3rd	5/4	7
	Major 6th	5/3	7
	Major 2nd	9/8	8
	Minor 3rd	6/5	8
	Minor 6th	8/5	8
	Minor 7th	7/4	9
	Major 7th	15/8	10
	Tritone	7/5	11
Diss.	Minor 2nd	16/15	11

Nominator

Denominator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	2	3	3	5	4	7	4	5	6	11	5	13	14	7	5
2	2	1	4	2	6	3	8	3	6	5	12	4	14	7	8	4
3	3	4	1	5	7	2	9	6	3	3	13	3	16	10	5	7
4	3	2	5	1	7	4	9	2	7	6	13	3	15	8	9	3
5	5	6	7	7	1	8	11	8	9	2	15	9	17	12	3	9
6	4	3	2	4	8	1	10	5	4	7	14	2	16	9	6	6
7	7	8	9	9	11	10	1	10	11	12	17	11	19	2	13	11
8	4	3	6	2	8	5	10	1	8	7	14	4	16	9	10	2
9	5	6	3	7	9	4	11	8	1	10	15	5	17	12	7	9
10	6	5	3	6	2	7	12	7	10	1	16	8	18	11	4	8
11	11	12	13	13	15	14	17	14	15	16	1	15	23	18	17	15
12	5	4	3	3	9	2	11	4	5	8	15	1	17	10	7	5
13	13	14	16	15	17	16	19	16	17	18	23	17	1	20	19	17
14	14	7	10	8	12	9	2	9	12	11	18	10	20	1	14	10
15	7	8	5	9	3	6	13	10	7	4	17	7	19	14	1	11
16	5	4	7	3	9	6	11	2	9	8	15	5	17	10	11	1

Figure 1: An illustration of Euler's Gradus Function. Some example frequency ratios are shown with their interval descriptions and 'degree of suavity'. Dissonance level is shown in the matrix in terms of colour (from green to red). Examples of pure consonances are shown in black, with Ionian and Locrian scale degrees in blue and white respectively.

Why this abstract mathematical model correlates significantly with listening experience is likely due to a) the presence of harmonic overtones (particularly the lower ones) in pitch instruments, and b) our physiological responses to the frequency spectrum. We are extraordinarily sensitive to frequency content, we would not be able to tell vowel sounds, or even identify sounds without a deep ability to interpret the 'sonic canvas' (see Lecture One). When we hear sounds together we inherently sense the amount of 'harmonic matching' which results in a fusion. Mismatching is — for lack of better terms — a little rough and gritty (Figure 2 shows how octave, perfect 5th, major 3rd and minor 2nd intervals line up in terms of harmonics providing some kind of objective measure of CD).

[1] For those so inclined, Euler's *Gradus* function can be formalised as $G(p/q)=1+\Sigma ei(pi-1)$ where p,q are relatively prime, the pi are the prime factors of pq and ei is the multiplicity of pi. Note that 'agreeability' increases with the higher number, but we can assume that the reverse is iplied if we equate 'agreeable with smooth'. Lower numbers feel 'smoother' and 'agreeable', higher numbers are more 'rough' and 'disagreeabke'.

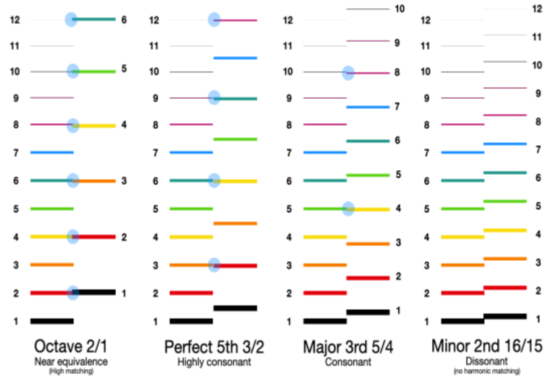

Figure 2: Harmonic matching patterns in octave, perfect 5th, major 3rd and minor 2nd intervals. Matched harmonics (and correlated level of 'smoothness') are marked with blue circles.

This perspective has quite profound implications. It not only shows the physiology behind 'roughness' when notes are played together in intervals and chords, but these can be broken down into rhythmic relationships, providing insights into dissonance in the temporal (i.e. horizontal) domain. Slowing down intervals producing rhythms with similar levels of consonance and dissonance. We could in fact rotate FIgure 2 to represent consonant and dissonant rhythmic (horizontal) relationships (see 'grouping dissonance' in Lecture Two). The 3/2 (Perfect 5th) relates to the *tresillo* pattern and continuous groupings in 3 such as Ellington's *It Don't Mean A Thing* 'doo-wops'. Britten's *Passacaglia* from *Peter Grimes* can be conceived as a set of harmonic intervals, a 'rhythmic chord'. Radiohead's *Let Down* has an Euler suavity of 8, while Meshuggah's *Rational Gaze* sustains a juicy 25/16 rhythmic ratio - a rhythmic minor 6th (a suavity of 13).

Harmonic matching also reveals how the *timbre* of an instrument might induce similar roughness. This is well known to musicians who will manipulate their voices, playing technique and instruments themselves to explore their spectral content for expressive effect. Such devices as vocal belting, bowing angle and pressure, guitar distortion and wah-wah exploit our listening faculties to produce a countless range of dissonances and musical experiences.

Intervallic Flavours

Let's move beyond intervals and look at the dissonant quality of chords and scales. How do we explain the consonance of a major pentatonic, the mystery of a minor(major 7) chord, the eerie acentric floatiness of the whole tone scale or the satisfying scrunchiness of the Hendrix chord? We can make a quick but rewarding insight by simplifying the problem significantly. Firstly let's assume 12 (equally tempered) notes and 'octave equivalence'. That is to say all pitches octaves apart are 'the same'. So all Ds (no matter their octave) belong to the same 'pitch-class'. There are only 12 pitch-classes which we can arrange in a circle — a *chromatic clock.* Secondly, let's consider intervals as a distance between pitch-classes, but be ambivalent about *direction.* For example, a semitone *up* (e.g. minor 2nd) is the same as a semitone *down* (or even a major 7th). This gives us only 6 ways to connect any two pitch-classes: 6 interval classes (ic1–6 for short). These interval classes have differing levels of dissonance – and different 'flavours'. Interval class 1 (ic1) is the highest level of dissonance, while ic5 is the lowest. These are shown in the left hand side of Figure 3 along with theorist/composer's Vincent Persichetti's description of them. We lose musical detail from the constraints of this perspective (what's known as pitch-class (or musical—) set theory), but within these constraints we gain the ability to *present any chord or scale imaginable*[2]*.* These we can see as a geometric shape in this chromatic clock, constructed by combinations of these interval classes. The major triad for example is made up of a major third (ic4) between C and E of a C major chord, a perfect 5th (ic5) between C and G, and a minor 3rd (ic3) between E and G. This creates an intervallic 'flavour profile' with the stability of the perfect 5th (ic5) and the soft consonances of the major and minor 3rds (ic4 and ic3). It avoids the 'restless' tritone (ic6) and dissonant ic1. We can represent this mix as an *interval vector* such as <0 0 1 1 1 0> where each slot shows the number of each interval class in the chord. Figure 3 shows the

[2] The complete catalogue of pc-sets (pitch-class sets) have been catalogued and named by an originator of the field, Allan Forte. Every possible pc-set is given a unique identification code, or *Forte Number*. For example, the whole tone is the 35th hexachord (six note object) with Forte number 6-35.

interval vectors of a selection of chords and scales. Note the avoidance of the most dissonant intervals (ic1 and ic6) and significant consonance (ic4) in the major triad and pentatonic scale. The unstable symmetry of the diminished 7th chord, and the 'gapped' acentric vector of the wholetone scale. The diatonic scale, though maximising the number of possible perfect 5ths, contains every interval class showing how it can be used for some levels of dissonance.

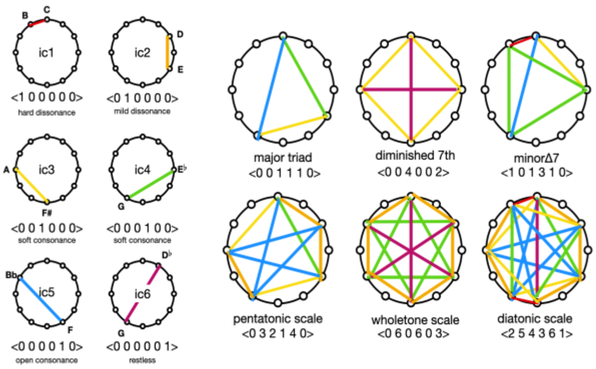

Figure 3: The six interval classes, and a selection of Interval vectors for scales and chords with a range of 'flavour profiles'.

We can think of the intervals in these harmonic objects as handshakes or clinking glasses between people. Every person (or note) makes contact with every other. We can actually calculate the number of intervals (i) from the number of pitch-classes: i = (p * (p-1)) / 2. So with a 3 note chord we get (3*2)/2 = 3 intervals. A pentatonic scale has (5 * 4)/2 = 10 interval classes, a 7-note scale has 21 and so on. A four note object (a *tetrachord*) has 6 intervals, and it is in fact possible to arrange the notes so that each of the 6 interval classes are represented (a vector of <1 1 1 1 1 1>). This elegant harmonic object creates an efficient 'intervallic richness', economically triggering each of the intervallic flavours. Such a configuration is known (quite logically) as an *all-interval tetrachord* (AIT). There are only 4 possible AIT shapes and one of these happens to be the Hendrix chord[3] (illustrated in Figure 4). When I discovered this property, it was a cathartic experience demonstrating the connection between objective mechanics and subjective experience. I had grown up transfixed by the visceral richness —the direct unfussy dissonance — of the Hendrix chord and here is its hidden but crystal-clear underlying structure.

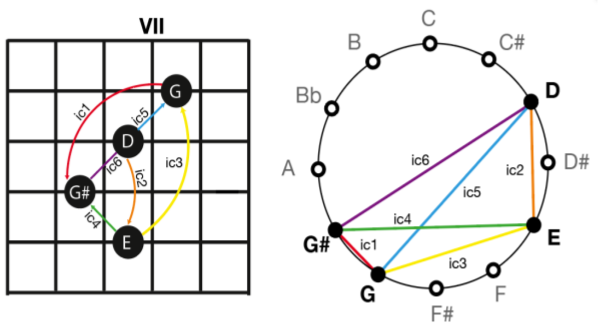

Figure 4: The 'Hendrix Chord' represented as on the fretboard (left-handed version available), and the chromatic clock. It is one of just 4 possible 'All-Interval Tetrachords'. All interval classes are represented just once (its interval vector is <1 1 1 1 1 1>) giving it a maximally efficient intervallic richness.

How Near or How Far: Musical Distance

Vertical pitch-based dissonance helps explain why certain chords with high levels of dissonance 'want' to resolve to more consonant chords. Dissonance can have horizontal implications of tension and release. Indeed, in standard jazz practice, dominant 7 chords are often used as unstable points of tension in order to resolve into other more consonant 'target' chords. These 'functioning' dominant 7 chords tend to be the most tolerant of dissonance and intensified with 'altered' extensions (such as b9, #9, b13) to add to the spice. It's as if knowing that the chord will resolve we can endure the dissonance more readily. Alternatively, when dominant 7 chords are used as 'stable' chords (as in the first or last bar of a blues) they

[3] The Hendrix chord has Forte Number 4z-15.

tend to have more consonant extensions (9ths and 13ths). Vertical dissonance can imply tonal centres, and temporary journeys.

However, dissonance is not only caused by a vertical roughness but a sense of musical *proximity*. How similar or different two motifs are, or how 'far away' two notes or chords are perceived can also create a sense of home and journey, centre and perimeter, resolution and tension, How we form such categorisations of musical objects is psychological, cultural and learned through repeated listening – as opposed to the sensory physiological dissonances of the harmonic spectrum. It is still surprising how intuitively and quickly such categorisations are made. For example – to many Western listeners – a C major triad and a D minor triad are 'closer' than C major and C# minor. Why is this? C major and C# minor share one note, and the other two each move only one semitone (they have a *chromatic distance* of just 2 semitones). C major and D minor share no notes (and have a chromatic distance of 5 notes). So why do C major and D minor 'feel closer'. An explanation is illustrated in Figure 5 where the three triads in question are presented 1) Left: In a chromatic clock (where C# minor is close to C major in terms of chromatic 'voice-leading distance' and 2) Right: A circle of 5ths, where the closeness of C major and D minor is apparent, collectively completing a 6-note 'arc of fifths' and Ut-La hexachord (see Lecture Four).

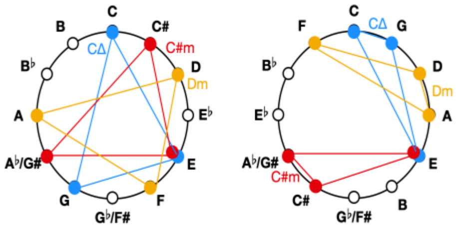

Figure 5: C major, C# minor and D minor on a chromatic clock (left) and cycle of 5ths (right) showing significant degrees of distance in musical space.

Such musical spaces help us understand this intuitive sense of the 'dissonant distant' in the musical experience. A piece of music — and prior listening – can weave the contextual space in which it inhabits. Euler – again – first proposed the idea of a *tonnetz* – a 'pitch surface' on a lattice of intervallic relationships producing a field of proximity of chords. This will be explored in Lecture Six, but an illustrative and well established *tonnetz* is shown in Figure 6. Pitch-classes are arranged in perfect 5ths from left to right, in major 3rds (diagonally from bottom left) and minor 3rds (diagonally from top left). Major triads and minor triads are thus represented by upright (red) and upside-down (blue) triangles respectively. Adjacent triads share notes and have close voice-leading proximity, and so in some musical contexts the *tonnetz* provides a meaningful representation of distance and a journey through harmonic space. Chords a large distance away create surprising and dissonant jumps. This pitch surface can also capture the essence of 'tonal languages': Diatonic progressions and chord collections tend to collate in the West-East direction (white arrow). The 'magical' *hexatonic* language of late Romantic composers from Brahms to Liszt to Franck) connects chords in the North-East line (purple arrow). The more gritty, octatonic language of Rimsky-Korsakov and other 20th century composers (from Bartok to Prokofiev to Stravinsky to Piazzolla) collects chords in the North-Westerly direction. This tonal language has some extraordinary properties, for example it allows C major and F# major (conventionally extremely distant chords a tritone apart) to co-exist at the same moment, such as Stravinsky's *Petrushka* polychord.

You Can't Always Get What You Want: The Painful Joy of Prediction

Music involves a continual set up of predictive frameworks such as establishing a pulse, a central pitch, recurring melodic objects and grammatical structure. Musicians (as discussed in Lecture Two) are poets in this art of prediction, creating expectations of likely continuations and then meeting, thwarting or twisting these in a variety of satisfying consonances or startling dissonances . Due to the multi-level nature of music such expectational meeting and thwarting can – and often does – happen simultaneously. Examples abound. Take Chopin's *Prelude No.4 in E Minor.* The entire melody outlines a gradual and easily accessible descent down an E minor scale from B to E. However the first time through the melody the final resolution is evaded both harmonically and melodically, our predictions are thwarted. The melody repeats and finally reaches the expected root note of E, but the chord is not the root chord. We are satisfied melodically but not harmonically. The tail end of the melody tries again but is met with a *different* surprise chord. And two more times the final root note is met with a 'wrong' chord. It's only when we hear the root note for the 5th time does it finally marry with its root chord. None of the surprise chords are particularly dissonant, but this continued thwarting of the inevitable resolution has a painful yearning, in keeping with the piece’s tragic atmosphere. In fact it is this choreography of expectation and surprise, as much as the surface material, that makes up its musical power.

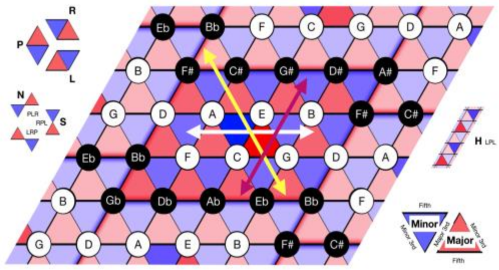

Figure 6: The tonnetz, a lattice of pitches showing voice-leading proximity of the twenty four major and minor triads. A diatonic, hexatonic and octatonic collection of triads are shown

Meaningful Pleasure

Pleasure — what the ancient Greeks called *hedonia* — is an essential component in our survival. It relates to the simple sensory fulfilment of food, sex and other temporary rewards, but it can also be used as a mechanism in a ‘higher level’ of human flourishing and fulfilment, a ‘meaningful pleasure’ what might be called *eudaimonia.* Recent scientific research — particularly at Professor Morten Kringelbach’s *Centre for Eudaimonia and Human Flourishing* — has found actual neurological mechanisms in our experience of pleasure. As outlined in a 2024 Neuron article ‘Building a science of human pleasure, meaning making, and flourishing’ — *eudaimonia* — depends on a fully functioning ‘pleasure engine’. This involves a cycle of three phases: *wanting* (the anticipatory hunting for something in the world), *liking* (the hedonic rewarding satiation of that hunger) and *learning* (having met a need, an increase of experience and knowledge of the world for the future). Any of these phases in isolation may have a low level of pleasure but won’t provide complete fulfilment. Addiction (to drugs and smartphone ‘doom scrolling’ etc) traps us in a perpetual wanting phase. Reward (*liking*) without effort or growth — or *learning* detached from real world experience — lack meaning. But when these three phases are well correlated in a ‘whole-brain orchestration’ they trigger *hedonic hotspots* and an integration of brain dynamics which produce intense and sustainable forms of pleasure. It is hard to find a better description of musical experience than a continual cycle of challenging predictions, reward and learning which in turn feeds future predictions. Nor is there a much better explanation to why music is at once so addictive, nourishing, challenging and pleasurable. Music — like exercise, courting, climbing a mountain, cooking, deep learning — requires an effort, a struggle, a wanting phase before the simply pleasurable – a dissonance, before the consonance, and a resulting *learning* that feeds future predictions. With music this experience is both personal and communal. It involves the externalisation of the inner world, so that the struggle with — and love for — music may be shared.

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Web Resources

Euler's *Gradus Suavitatis* calculator. Available at: https://www.mathematik.com/Piano/index.html

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