The Evolutionary Origins of the Simple Integer Frequency Ratios in Music:
sexual selection for musicality indicative of spatial-temporal intelligence and integer processing ability.

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PROJECT SUMMARY

Problems

For centuries, philosophers, scientists, anthropologists, and musicologists alike have pondered the origins of musical scale structure. The twelve-tone equal temperament [12TET] scale of western music, though hardly universal, has a key characteristic that is seen across cultural and taxonomic boundaries, namely, the presence of simple integer frequency ratios [SIFRs]. Because SIFRs so closely approximate common musical intervals of 12TET (unison 1:1, the octave 1:2, perfect fifth 2:3, and perfect fourth 3:4), many have speculated that some underlying universal numerical phenomenon governs musical scale structure. While some have demonstrated biological innateness for SIFRs preference, others have refuted these claims with often time equally convincing evidence. Problems stemming from distinguishing between SIFR preference, dissonance avoidance, and cultural influences further cloud the issue. Arguments for biological innateness of SIFRs also suffer due to lack of suitable adaptive mechanisms for the evolutionary origins.

Objectives

In this proposal I will outline why the two main scale structure philosophies: cultural and natural (including biological and physical) are incomplete in explaining the origins of SIRF based music. I propose that an evolutionary theory unifying the approaches is both necessary and possible. I discuss how cultural determinants of SIFRs in music are not immune to environmental influences and can therefore evolve in a manner similar to that of the biological determinants. I put forward the idea of an "integer processing center" [IPC] in the inferior parietal region of the brain of musical species that analyses frequency (pitch and rhythm) and numerical relationships in general. I discuss the fundamental connection of the IPC with spatial-temporal intelligence [STI] and tasks such as brachiation, flight, ballistics, and navigation. I discuss current issues on the role of sexual selection in music, adapting older physical views into evolutionary arguments for music as a non-functional exploitation of biased sensitivities (*aesthetic* sexual selection). I finally, however, propose a sexual selection model for musical origins in which mate choice for expression of integer processing ability, via SIFR musicality, is *indicative* of adaptively useful STI. In short, I set out to prove that music evolved as a way to communicate spatial-temporal intelligence to a potential mate.

Methods

Inter-species Convergent Evolution: Research for convergent evolution of SIFR musicality will involve acquisition of recorded vocalizations of and environmental data collection for phylogenetically distinct vocal species. I will collect statistics regarding spatial-temporal demand of the each species' environments with emphasis on dementionality of each environment and number of grasping limbs. I will also collect data pertaining to frequencies of colors in each species' environments with special attention to dietary and anatomical pigmentation patterns. Finally, performing spectral analysis on each recording will enable me to both attain information on SIFR use and harmonicity of the species vocal apparatus.

SIFR-STI Correlation in modern-day humans: Further research will look at the historical development of human musicality in particular and the possibility of ballistics (via hunting and warfare), tool making, and abstract mathematical thought as other spatial-temporally demanding factors. The possibility of demographic and statistical analysis of occupational correlation with musicality is also discussed.

SIFR-STI Correlation in pre-historical societies: I will also compare the archeological records for STI tools and SIFR instruments. Quantitative measurements on the occurrence of pre-historical instruments such as bone flutes, and bows in comparison with the occurrence of ballistic instruments such as wooden spears will allow me to compare the early prevalence of SIFR musicality with STI as embodied in ballistic hunting.

The research proposed will be the first of its kind investigating the evolutionary influence of a selectively advantageous trait on the origins of music.

PROJECT DESCRIPTION

Background: Nature vs. Nurture in Scale Structure Origins

“Intonational Naturalism”[1]

Earliest Physical Inquiry. The physical explanation emerged as early as the fifth century B.C. with Pythagoras who discovered that subjectively consonant intervals were associated with simple frequency ratios (Fig.3). Since then, the physicists have divided: one group now focusing on absence of dissonance, and the other group on presence of order.

Avoidance of Roughness. This dissonanance group has explained subjective musical appreciation in reference to what the ear/brain mechanism finds displeasing or dissonant. 19th century physician Herman Helmholtz, progenitor of the law of conservation of energy, and father of the Helmholtz resonator, was the first to theorize that “roughness” between non-identical harmonics is responsible for dissonance and ultimately scale structure. Roughness can be described as a local maximum of unpleasant sensation intermediate between pleasant beats (amplitude fluctuations due to destructive and constructive interference of slightly mistuned frequencies, as shown in Fig.4) and the sensation of hearing two distinct tones (Figs.5&6). Because simple ratios line up harmonic tones in such a way that the partials of one tone either completely miss each other or exactly line up, the least dissonant (or most consonant) intervals will be those with simple ratios (Figs.7&8). Others who have expanded upon this explanation have included the idea of critical bandwidth, and amplitude dependence to more accurately map out the relative dissonance of musical intervals (Plomp & Levelt, Kameoka & Kuriyagawa, Sethares). This theory is able to explain the “calmness” attributed correctly re-scaled non-harmonic music of other cultures of the world. It allows for accommodation of these instruments in which simple frequency ratios no longer correctly lineup the (no longer integer-related) partials. The non-harmonic metallic gamelan of Southeast Asia, for example, is tuned in accordance with minimizing dissonance, yet produces a scale structure far from SIFRs. Ironically, however, the most prized[2] of all southeast Asian instruments, the non-harmonic gong, has a spectrum which yields, by the same scale generating methods, a “just” [western] pentatonic scale, with SIFRs of 1:1, 4:3, 3:2, 5:3, 7:4, and 1:2 (Sethares 1996). Another problem with the dissonance avoidance explanation is that the case of minimum dissonance is silence. If music is about reducing dissonance, then why does it paradoxically require the use of noise at all?

Preference for Order. The order preference group avoids this ‘maximum consonance through silence’ paradox…somewhat. This group argues that music is appreciated for the simple mathematical ratios themselves. Put another way, it is the appreciation of order and pattern that drives subjective consonance. Galileo was the first to publish this idea, illuminating an analogy between musical ratios and pendulum swing ratios. He wrote, "Agreeable consonance's are pairs of tones which strike the ear with certain regularity"(Galilei 1638, p147) He made the comparison that simple frequency ratios in the periodicity of swinging pendulums are appreciated as ordered to the eye in the same way that simple frequency ratios in musical intervals are appreciated as ordered in the ear. Physical order theory remains the oldest, the most simply stated and it is probably the one of the least popular among consonance theories today. The theory might be gaining more momentum lately though. Daniel J. Levitin at McGill University describes the order preference influences for musical origins: "Our brain is constantly trying to make order out of disorder,” he writes “and music is a fantastic pattern game for our higher cognitive centers." Although some have proposed “processing ease” for SIFRs (a form of simplicity appreciation)

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[1] Perlman (1996) uses this term to describe the belief that there is a natural, biological, or physical reason underlying musical scale structure. “Seventeenth century scientist Christian Huygens conjectured that, since “the Laws of [Western] Musick are unchangeably fix’d by Nature,” they should hold not only for the entire earth but for the inhabitants of other planets as well.”

[2] “According to tradition, gongs are of divine origin, and were used as a signaling system among the Gods” (Sethares 1996)

as a driving influence for the structure of music around simple integer frequency ratios, there is little reason to think we go through the trouble to learn music just because it is easy to do so. Aside from its lack of scientific support, the theory also has a problem similar to that of the previously mentioned dissonance avoidance theory. The question remains: if simplicity of frequency ratios governs musical appreciation, then why do we venture from unison at all? Why does music have any other ratio than 1:1? If music were about maximizing simplicity, all rhythm would be perpetually evenly spaced and all pitches would be the same, resulting in exactly one ideal piece of music: a monotonic perfectly rhythmic metronome. Because music is obviously not structured in this way, it is tempting to suspect that the order theory is mistaken. There are some aspects of the order theory, however, which bolster its foundation. The order theory, better than any other theory, can explain the cause for subjective sadness of the minor key. Although both relative minor an major keys (A minor and C major for example) use the same seven notes, the minor key is less ordered because the third has a ratio of 6:5 when it could have a ratio of 5:4, had the performer chosen a different tonal center for the same set of seven tones. It is sad because things could have been more ordered than they are in a minor key choice.

Physical explanations. Physical explanations of scale structure fail to account for the vast majority of music that usually does venture from unison (not to mention silence). Although any model tested at its extremes will most likely fail, it is important to note that the extreme predictions of these theories do fail. Music is an exercise *in* as well as *away from* simplicity. It is an adventure in pitch relationships and rhythmic structures, simple and complex. Even if we can rule out either of these theories as the sole cause of musical scale structure, however, it doesn't mean they cannot contribute in meaningful ways to a multiple cause model.

Biological Templates and Harmonic "Fusion": Lenard Bernstein states that "All music, whether folk, pop, symphonic, modal, tonal, atonal, polytonal, microtonal, well-tempered or ill-tempered, music from the distant past or imminent future, all of it has a common origin in the universal phenomenon of the harmonic series" (Bernstein) Other theorists have proposed that SIFRs, because of the harmonic series, sound more "fused;" they are all part of the same frequency relationship that the brain expects to hear (Hartman, McAdams, & Smith). Pantev has discovered that the auditory cortex is organized not only by absolute frequency but by pitch as well. Individual cells have also been cited as possessing multiple (SIFR related) tone responses. This would seem to indicate that the ear/brain machinery almost expects certain tones to be sounded in conjunction. Certain psychological studies have shown, despite strong contrast between trained and untrained listeners, that some preference for simple ratios occurs (Shellenberg 1994). The long pattern hypothesis theorizes that the brain prefers simple repeating patterns (Boomslitter & Creel). Both octave and consonance preferences have been demonstrated in monkeys (Wright and Izumi). And an overall simple Structural appeal explanation has been proposed (Sloboda). And although this evidence explains the universal nature of SIFRs in music, the question remains as to what evolutionary forces have selected for this biology.

Intonational Relativism

Biological counter: Before I have speculate on any naturally selective mechanisms responsible for the hardwiring of SIFRs, however, I will review some very convincing evidence that the hardwiring simply doesn't exist. There have been a number of studies that seem to refute the evidence for a biological innateness for the octave and SIFRs. Edward Burns, from the University of Washington, has shown how Shepard's tones (an illusion attributed to octave equivalence) are probably not biologically encoded. A non-octave version can easily be trained into subjects yielding a non-octave equivalence. Burns and others have also shown that the studies suggesting discernabilty of SIFRs by non-trained listeners are largely mistaken. Other studies have also shown similar non-octave results in starlings (young birds), deaf birds, human children, and the musically untrained in general. Cord priming experiments by Tekman

& Barucha have shown the way in which listeners where trained to recognize certain atypical chords over more traditional chords.

Cultural explanations: The work-song theory, advanced by Karl Buecher, proposes that music found its place as a rhythmic coordinator for efficient work. The theory of rhythm suggests a similar purpose: music for dance accompaniment. The need for human communication over long distances has also been proposed as a stimulus for music in the calling signal theory (Revesz). Speech linked theories are also many in number. A currently popular theory, the lullaby theory, proposes that as the need for investment in offspring increased in the ancestral environment, a mother would establish bonds and soothe a child by fluctuating her voice into simple melodies. The impassioned/expressive speech theory proposes that music arose out of similar fluctuations in voice pitch during passionate speech. The theory of melodic speech similarly proposes that speech preceded music but contrasts in that it dismisses the necessity of passionate speech and instead suggest that normal recitative speech pitch fluctuations evolved into music. A more inclusive suggestion has been to place some intermediate semi-linguistic and semi-musical form of communication consisting of "grunts" and "cries" before both modern music and modern language as their common evolutionary root. While these explanations for the origins of music seem to grow closer in looking for a root cause for the evolution of music (more 'why' instead of 'what'), they fail to address the issue of SIFR universality in musicality and ignore the adaptive possibility of using SIFRs.

Evolutionary Considerations: The Solution to the Nature vs. Nurture Controversy

Background

Cultural evolution: There remain three possibilities: 1) music has evolved through cultural evolution (Dawkins 1976), 2) It has evolved through natural selection or 3) it has evolved through sexual selection. We can begin to rule out 2) as it seems fairly obvious that music offers no direct survival value to its practitioners. 1) seems possible but fails to account for the universal reach of SIFRs and a majority of tests on deaf animals who still seem to have some ability not only to express themselves musically but in accordance with SIFRs. Geoffrey Miller writes, "Music is a biological adaptation, universal within our species, distinct from other adaptations, and too complex to have arisen except through direct selection from some survival or reproductive benefit." That leaves us with sexual selection.

Sexual Selection Charles Darwin, in 1871, proposed the first sexual selection theory, exploring the possibility of selectable song. His theory, often referred to as the "mating call theory," suggests that song evolved as a way for a male to entice a female into a reproductive relationship. He writes, "...it appears probable that the progenitors of man, [] before acquiring the power of expressing their mutual love in articulate language, endeavored to charm each other with musical notes and rhythm" (Darwin 1897). Though Darwin's approach to sexual selection (via mate choice rather than aggressive male rivalry) has been largely neglected for the past 100 years, a recent resurgence has occurred. Contemporary naturalists have explored two main aspects of female decision-making: mate choice for indicators and mate choice for aesthetic displays (Miller, 1998). Although there is entire camp of theorists which maintain that some sexually selected traits occur as exploitations of biased sensitivities within a mates wiring (Fisher 1930), I will be making a case for sexually selective choice which is *indicative* of some underlying trait (Hamilton & Zuk, 1982).

Mate Choice for Aesthetics: Some of the previously mentioned theories of Dissonance avoidance and Order Preference have been recently looked at in terms of evolutionary forces. Kamo& Yoh, have discovered, using computer simulations, that preferences for consonances may have evolved as a “by product” of some of our other preferences for order, suggesting that aesthetic sexual selection is acting. I suppose that a predisposition for organization may occur, an “order instinct” if you will. Yet I fail to be convinced that the order instinct would be great enough carry the weight of musicality, a far more biologically secure phenomenon. Linguist Steven Pinker, of MIT, on the other hand, has suggested the deeply instinctive ability for language processing could have provided the necessary momentum for music slip through the generations unnoticed. He has proposed that music is merely "auditory cheesecake," or "an evolutionary accident piggy-backing on language." I have doubts, however, that he has a sufficient explanation for SIFRs in music.

Mate Choice for Indicators: William Calvin debates this same issue “The evolution of musical ability probably came along with the more general selection for structured thought, what we call higher intellectual function. But there is a chance that sexual selection also acted on it.” Although he may be referring to sexual selection in an different sense than Miller, It seems as though he might be siding with mate choice for music as an indicator for structured thought. In contrast however, I want to make clear that I am suggesting that music evolved as an indication of a specific form of structured thought: namely integer processing and perhaps spatial intelligence.

The First, Not Necessarily Harmonic, Instruments

Harmony Before Melody? Darwin writes on this issue, “Helmholtz has explained on physiological principles why concords are agreeable, and discords disagreeable to the human ear; but we are little concerned with these as harmony in music is a late invention. We are more concerned with melody.” Helmholtz, however, recognized this possibility of melody predating harmony as problematic for his theory and explained that memory comes to the rescue in explaining melodic structure. Supporting this memory defense of ‘harmony first,’ Sethares has suggested, in lieu of experimentation with bi-aural simultaneous intervals, that the mind probably can perceive (and thus avoid) a *melodic* roughness between non-simultaneous intervals. This argument, along with other evidence of non-harmonic yet consonant music generated and collected by Sethares, seems to refute the notion that scale structure depends upon SIFRs. If harmony predated melody, the harmonic series predating SIFRs, then the structure of musical scales would be solely attributable to the natural spectrum of each particular instrument (as well as our aforementioned aversion to roughness). Scale has evolved around SIFRs because physical laws dictate the harmonic series for most instruments.

Non-Harmonic Proto-Musical Instruments: Yet I would argue that this last point is not necessarily correct. The harmonic series can only be realized in highly idealized constructions such as an infinitely thin strings and an perfectly cylindrical tubes. Modern musical instrument designers with access to all of the high-tech scientific techniques of recent times sometimes even have trouble reaching such perfection necessary for production of an exactly harmonic series. I imagine our ancestors had much more difficulty trying to do the same on less technical knowledge and poorer quality raw materials such as stone and wood and perhaps bone.

Voice as the Non-Harmonic First Instrument: Even if these materials did occasionally generate partials which happened to coincide harmonically, they would probably have little influence on the very early development of musicality. This is because we can safely assume that the voice was the first musical instrument (Ewens 1995). More importantly, we can also probably safely conclude that the voice was far from the ideal unchanging tube or string instrument necessary for the creation of an ideal harmonic series. Rather, the voice, like its closest relative, the mouthpiece of a reed instrument, produces a very noisy spectrum: non-harmonic most of the time. Recent investigations into the “non-linearity” and chaotic nature of the vocal folds have shown that human infants and many other mammals tend to produce predominantly non-harmonic vocalizations (Wilden et al., Mende et al). This seems to indicate the ability to create harmonic sounds is not only an predominantly human phenomenon but also an *adult* human phenomenon—suggesting that it is a learned ability.

SIFRs before the Harmonic Series: While I argue for a learned ability to *produce* SIFR in music, I am not advocating a learned ability to *process* SIFRs. While, although *development* of musical processing most definitely occurs during musical training, I suspect that the fundamentals for relative pitch and rhythm perception and processing machinery were largely inherited along with the rest of the IPC in the brain.

<u>SIFR Musical Expression as an Indicator for IPC:</u>
<u>Is there Adaptive value in IPC?</u>

SIFRs and STI: As stated in my thesis, I propose that the IPC serves as a ratio template for relative musical pitches related by SIFRs. But this IPC doesn't, at first glance to seem to have any sort of evolutionary advantage. The first possibility that comes to mind is that appreciation of ratios is important for the idea of number itself. Those who have an unconscious understanding of what a number is, will be more likely to survive because of it. This explanation, however, doesn't seem to work when we consider that cognitive abilities at this level, although useful today, were probably low down on the list of evolutionary advantageous cognitive function. Thus the question remains: why are ratios useful? Recent investigation into the correlation between number comparison abilities and spatial intelligence may provide the answer. Although a tight relationship between mathematical and spatial abilities has been empirically demonstrated, until recently no relationship has been made between number comparison abilities and spatial abilities. In fact, recent studies have shown, using positron emission tomography, that number comparison is actually a more primitive and instinctual mental ability, where as upper level mathematical operation (such as multiplication) is learned. The main area of interest is the inferior parietal region. It is assumed that both number comparison and spatial abilities are hosted by this part of the brain. Stanislas Dehaene writes of this area:

> "My feeling is that the inferior parietal region hosts neural circuitry dedicated to the representation of continuous spatial information, which turns out to be ideally suited to the coding of the number line. Anatomically, this area stands at the top of a pyramid of occipito-parietal areas that construct increasingly abstract maps of the spatial layout of objects in the environment. Number emerges naturally as the most abstract representation of the permanence of objects in space--in fact, we can almost define number a the only parameter that remains constant when one removes object identity and trajectory."

Because spatial intelligence, an arguably useful ability, appears to be so closely connected to the idea of number and number relationships which is in turn also closely related to the structure of music, perhaps the argument for music evolving as a means of primitive intelligence expression, gains greater validity.

Music and STI: Recent studies into the role of music in improving spatial intelligence serve to further support the model of sexual selection for SIFR musicality as an indicator of STI. This research, performed by Frances H. Rauscher, using the "trion" neural network model of brain processing, has uncovered substantial improvement in spatial-temporal intelligence for children partaking in musical training. Rauscher defines spatial-temporal intelligence as "Maintaining and transforming an image without the presence of a physical model." Paper folding and cutting [pf&c], in which subjects are asked into which "snowflake" a pre-cut an folded paper will unfold, is a typical test used to measure this ability in her experiments. If corroborated, this theoretical framework will provide strong evidence further linking numerically organized music with spatial intelligence. Rather than supporting her claim that musical training is responsible for developing STI, I am claiming that STI and the SIFRs of music both stem from a more primitive function hosted by the IPC where integer and spatial relationships become fused into one entity on the number line.

Uses for STI and the IPC : In the course of Primate evolution, many times, the importance, and survival value of spatial intelligence has been stressed. According to the visual predation hypothesis, sixty million years ago, primates adapted with stereoscopic vision and opposable first digits to an evolutionary niche in which insects were the primary dietary source. Thus as early as this, spatial abilities comes into play. With the branching off of the hominid line, Brachiation, or overhead arm-swinging came under evolutionary forces. The living form of this primitive hominid is the gibbon or siamang. It is easy to see how brachiation requires great spatial abilities due to its one hand at a time form of locomotion (a contrast is the orangutan which is quadrimoniuos--thus three limbs at a time). Early Hominids, as indicated by their development of ungular tufts at the finger tip and metacarpal head asymmetry (both indicative of hand manipulation) needed spatial abilities to manipulate objects. As the first concrete evidence for stone tool making is at about 2.5 million years ago, we can see how spatial abilities may have been an important part of hominid survival. I suspect, however, that the biggest selective pressure for spatial intelligence came later in Homo evolution: pressure for ballistic hunting.

Ballistics: William Calvin, from the University of Washington, has suggested, though without mention of spatial intelligence, that 'ballistics' have played an important part in the evolution of music. I speculate here, expanding upon Calvin's initial idea, that the ability to rotate a three-dimensional game ground in a hunter's mind provided the ability to improve trajectory and targeting. This abstract ability that probably evolved under tremendous selective pressure in times of sudden climactic changes and seasonal food shortages where hunting might the sole source of nourishment. This abstract ability, which evolved under selective pressure in times of sudden climactic changes and seasonal food shortages where hunting may have been the sole source of nourishment, enabled its possessor to envision trajectory, improve targeting and consequently the likely hood of getting meat, eating, potentially sharing his food with a mate, and eventually mating and producing more off-spring. I imagine that music followed as a relatively logical consequence from this evolutionary selection for the spatial intelligence so closely linked with integer processing.

It is likely that the music we see in many of the animal species today reflect not a similar genetic makeup but rather convergent evolution upon a need to communicate some newly acquired ability to parameterize and process mathematically the surrounding environment—an abstract ability so very difficult to exude in any more efficient way other than vocalized SIFRs.

Hypotheses

Ballistic hunting is probably the single greatest selective pressure prompting female choice for SIFR rich musical indicative of a IPC and consequently STI in humans. Additionally, SIFR use is likely to have arisen separately several times in phylogenetically distinct species due to similar spatial-temporal demand in each environment that required their inhabitants to develop efficient ways to communicate the adaptive abilities to one-another for either mating or territorial purposes. My theory is not that music makes people substantially smarter (except in very limited and not necessarily very useful ways), nor that only that only smart people truly appreciate music, or that the most spatially gifted have the most viable musical taste. I am asserting that music evolved as a way to communicate spatial-temporal intelligence to a potential mate.

Testing Psychoacoustic Theory

Psychoacoustic theory rests upon the assumption that all musical instruments produce harmonic sounds (sounds with partials related by integer multiples of the fundamental). I intend to exploit that assumption by showing that the first instrument, the voice, was probably unaccompanied and (at least initially) non-harmonic. Because there is no way of disproving the influence of culture in distinguishing between dissonance avoidance and the two theories which predict SIFRs in scale, I plan on using color which is relatively free of cultural biases and totally free of problems associated with isolating pure sine frequencies with no upper harmonics (visible light has no visible upper harmonics because the range is less than one “light octave”)

H1: Color blindness should occur along lines of SIFRs. Men should have a greater degree of color blindness

H2: SIFR based musicality should precede vocal harmonicity in every musical clad.

H3: SIFR preference should take precedence over dissonance avoidance cues in harmonic stretching experiments.

H4: Species living in spatial-temporally demanding environments should display a greater or equal degree of octave use than harmonicity.

H5: The voice should be capable of in-harmonicity and harmonic capability should be largely behaviorally controlled. (infants should have more chaotic sounding vocalizations)

H6: There should be some evidence for preference for simple integer frequency ratio preference and/or distinguishing ability for subjects exposed to light ratios.

H7: The ability to see color should be associated with musicality. (evolution of colored plumage?)

Evolutionarily Linking Spatial-Temporal Intelligence with Musicality

Although there has been significant work done in studies by Shaw and Rauscher linking spatial-temporal intelligence with musicality, none have looked at evolutionary relationships and ultimate environmental causes of the musicality of species.

H8: Ballistic devices should shortly precede musical instruments in the archeological record.

H9: Javelin throwers, quarterbacks, baseball players, etc. should all show signs of a natural talent for octave recognition in spite of little or no musical training.

H10: Species that live in spatial-temporally demanding environments should be musically vocal

H11: Cultures that have an unequal division of spatially demanding labor should exhibit a corresponding inequality in musical ability.

H12: Plants, which depend upon other spatially intelligent species for reproduction, should tend to have brightly colored plants (which compliment--via a SIFR--the green color of the rest of their foliage)

Pilot Research

I conducted very limited research on 11 of my nearby dormitory friends in May of 2000. The purpose of the research was to test between bio-cultural influences and psychoacoustic influences in musical interval recognition and appreciation. I constructed computer interface using PureData, a realtime, visual, data intensive audio program[3], with two complex tones one which was variable and one, which was fixed. I could control the number of harmonics of each of the tones, the fundamental frequency of the harmonics and the stretch of both of the tones away from perfect harmonicity. I allowed the users to control the fundamental frequency of the variable tone. The subjects were twice left in my room in front of my computer and told to rank their five "favorite" or "best sounding" tone intervals for both stretched and un-stretched tone pairs. One time I gave them a harmonically related tone, and the other time I left them with two stretched tones.

There were no significant findings, larger sample size would help in the future. Additionally, a greater stretch may be more important to distinguish the test and control (as the stretch was only from a control harmonic setup which placed the octave at a 1.00:2.00 ratio—normal--to the test stretched harmonic set up with an "octave" of 1.00:2.05—otherworldly sounding). This type of distinguishing test may serve useful in future research as mentioned in H3 above.

Methodology

I plan on doing most of my research analyzing the speech sound so of non-human species using SoundForge or some other Audio processing software. I will use the spectral analysis tools within this software to determine harmonicity of vocalizations. I plan to use this technique to test hypotheses 2,4,and 5.

I have not yet determined the methods I will use to analyze and produce exact frequency ratios of visible light. This is a recent development in my thinking and will take some time to sort out. This method will be important to test out hypotheses 1,6, and 7

Hypotheses 8,9,10, and 11 could largely be accomplished by book research and/or direct investigation via interviews and subsequent tests of both spatial intelligence and natural musical ability. I really have no Idea how best to go about testing these ideas without getting money for a large sample of people or to just do a lot of library research via an ethnographic atlas or other cross cultural summary. I have considered constructing an online test in which I could do psychoacoustic, visual, and questionnaire like investigations. This might be a strong approach as I could ask subjects to participate via e-mail and data entry would be automatic.

The Importance of this Research

This research will be the first of its kind testing an adaptive evolutionary model for the origins of musical scale structure. It is unique in methodology as well in that it addresses the possibility of using color. The method of using electromagnetic waves will provided a very useful analogy for the study of SIFRs in sound waves because it is largely free of cultural bias counter-arguments and problems associated with eliminating upper harmonics.

[3] written in C by Miller Puckette

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Figure 3.

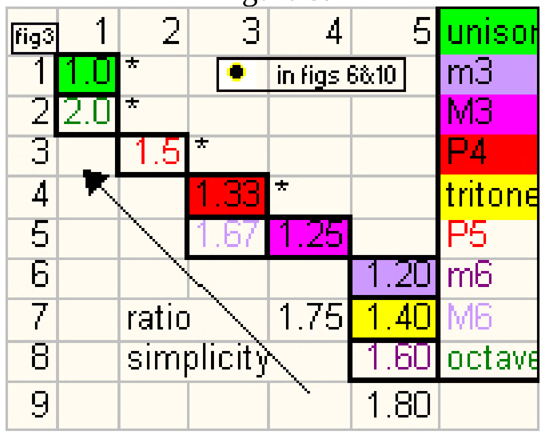


Figure 4

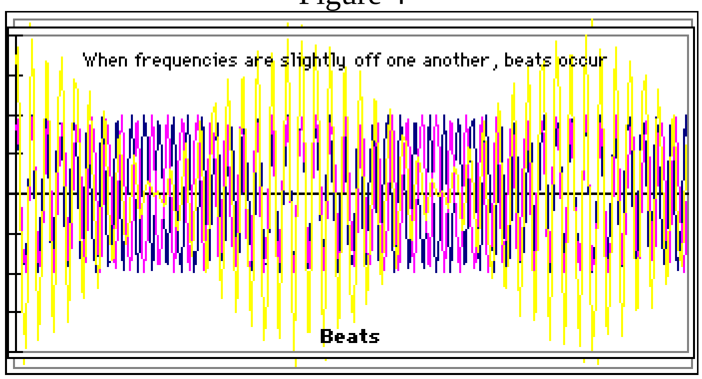
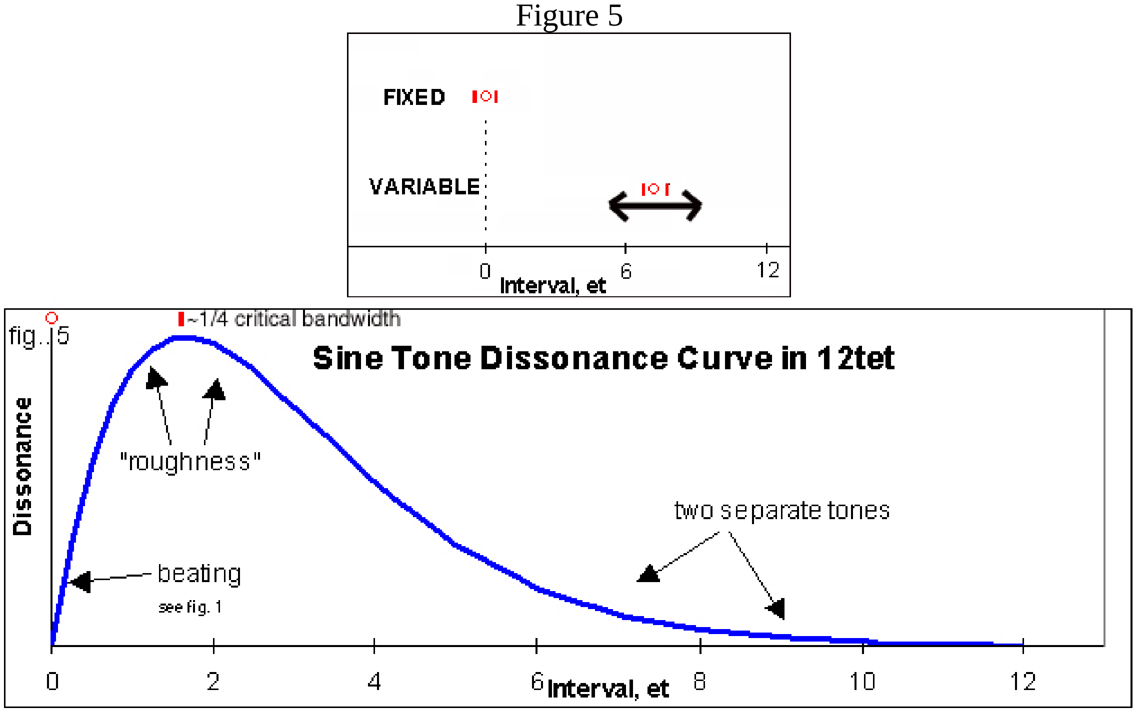


Figure 5



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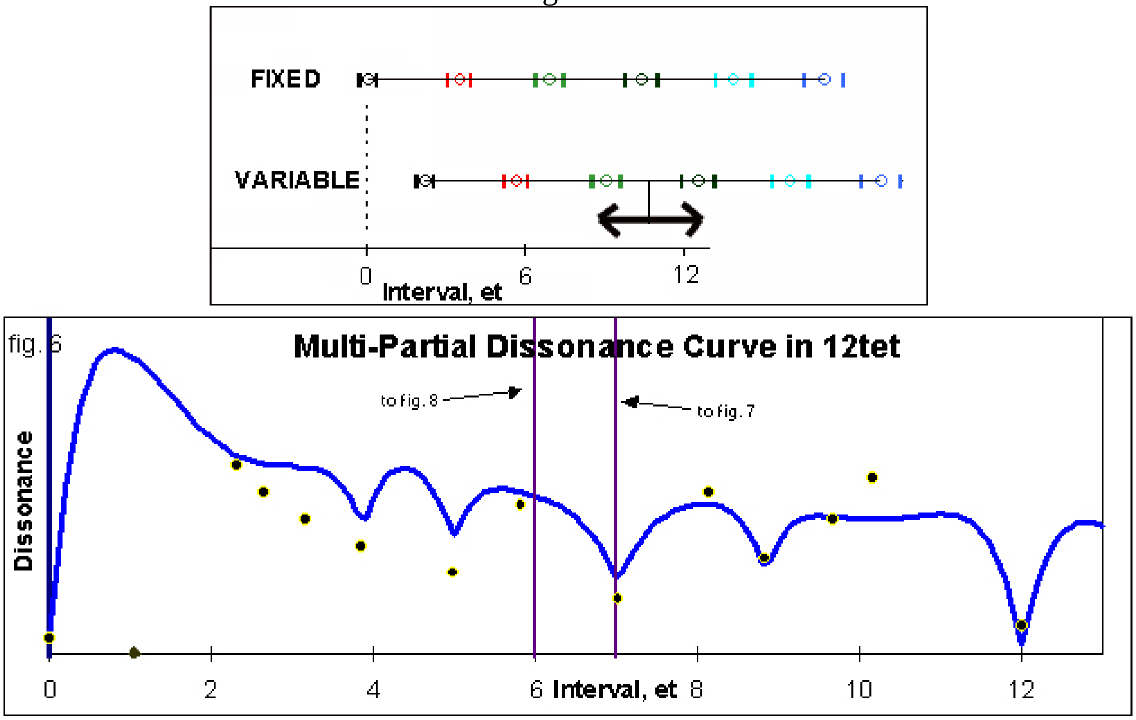

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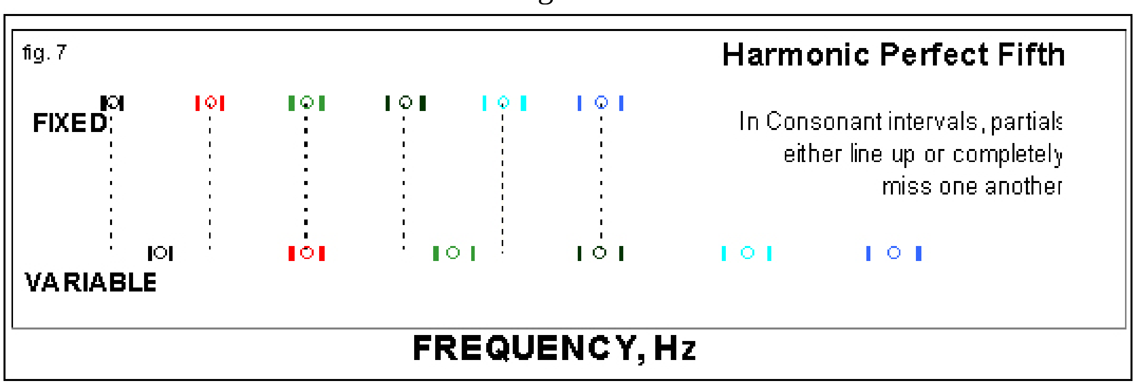


Figure 8

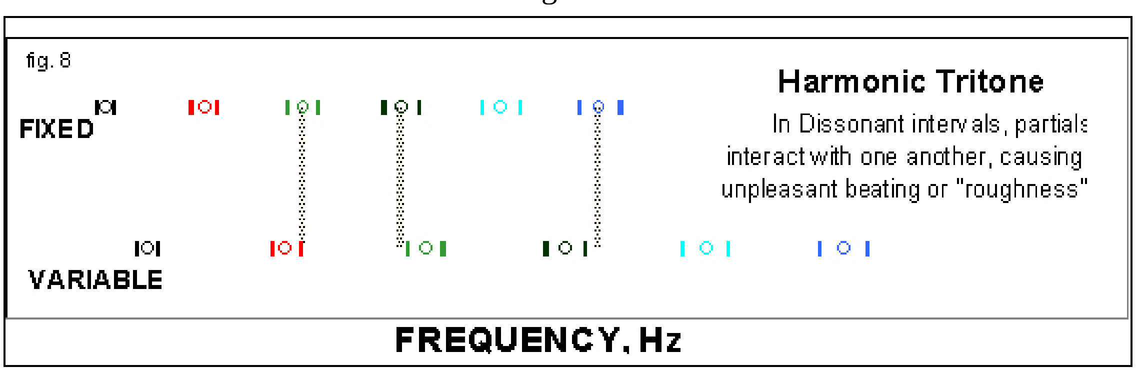
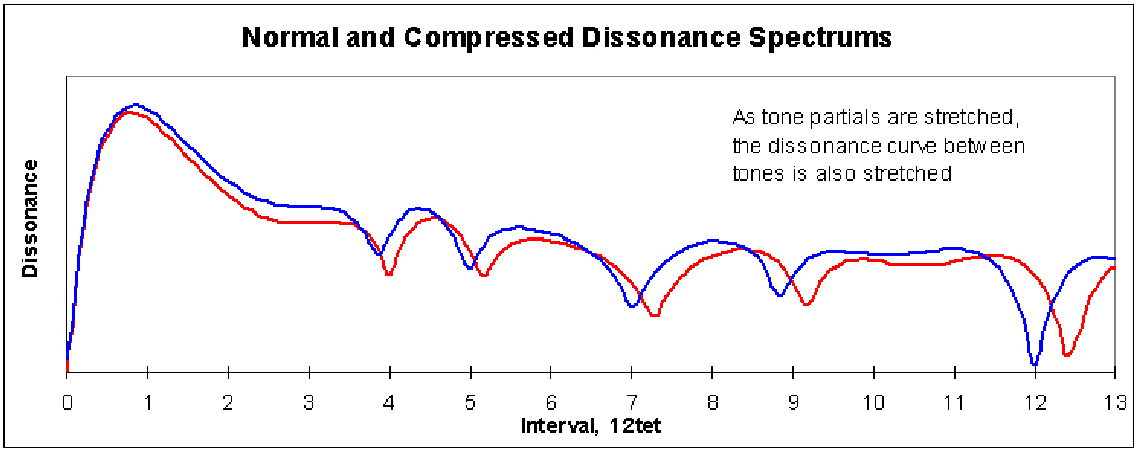


Figure 9


Normal and Compressed Dissonance Spectrums
Dissonance
As tone partials are stretched, the dissonance curve between tones is also stretched
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Interval, 12tet

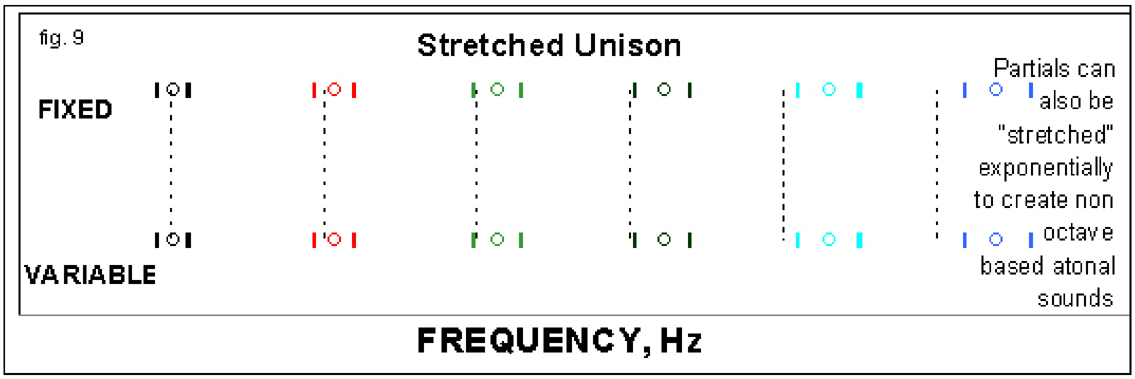


fig. 9
Stretched Unison
FIXED
VARIABLE
Partials can also be "stretched" exponentially to create non octave based atonal sounds
FREQUENCY, Hz

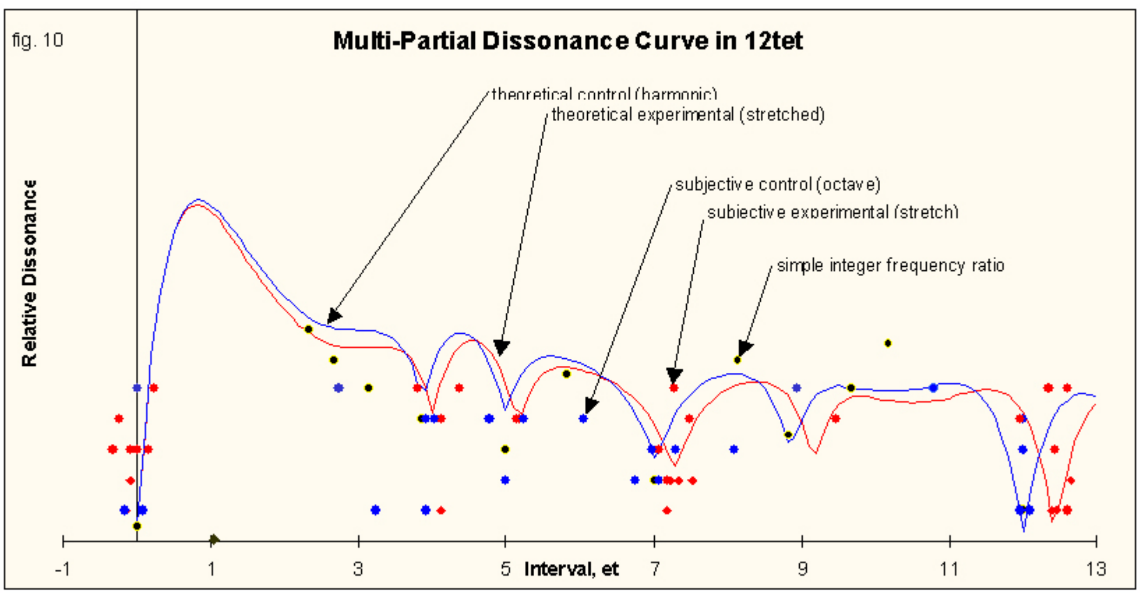


fig. 10
Multi-Partial Dissonance Curve in 12tet
theoretical control (harmonic)
theoretical experimental (stretched)
subjective control (octave)
subjective experimental (stretch)
simple integer frequency ratio
Relative Dissonance
-1 1 3 5 7 9 11 13
Interval, et