

- **Title – Statistical validation of a biopsychological geometric model for human musical experience**
- **Abstract:** We have developed a geometric model for human musical experience that combines an underlying biological signal of Darwinian fitness with a model of psychological impacts. The triangular architecture of this model seems to describe very well the existing genres of music. We want to statistically validate this model using confirmatory factor analysis (CFA) and measures of feature importance applied to musical genre in machine learning classification (MLC) tasks applied to sound files. We will tune our multivariate input measurements to the model to optimize the resulting CFA and MLC accuracy. Upon achieving good model performance, we will conduct a comparative study of expert vs. novice performers among human musicians. If possible, we will also adapt and extend the use of the model to compare expert vs. novice avian performers (i.e. bird song) using age as a proxy for expertise.
- **Description of the research team:** Drs. GA Babbitt (GSOLS) and EP Fokoue (SMS). We will accept as many students as possible who are interested in the project to work on python code, visualization, client-side application, and data collection. Students from biology, bioinformatics, math and perhaps performing arts programs will be recruited for this project.
- **Project timeline:** We will develop most of our initial codebase over the summer of 2025. We will use Fall 2025 to build a large database of mp3 files to be analyzed, primarily using YouTube as a source of sounds. Spring 2025 will be used to develop publication(s).
- **Budget:** \$3000.00 put towards 1-2 publications. The publication(s) will be likely be submitted to broadly disciplinary journals (e.g. Royal Society Interface). There will be no other expenses outside of publication fees. No money will be needed until acceptance of publication.

- **Project Narrative:**

What makes a sound musical? What is the origin and purpose of music? Is music a purely human endeavor, or part of the larger fabric of nature? These questions and similar others have been around for thousands of years, perhaps as long as music itself. The evolutionary origin of musical and artistic behavior in humans has long been a subject of archeology and many popular books. One point of view, borrowed from the field of behavioral ecology has been far less applied. Behavioral ecologists generally ask the basic question, "To what advantage does a behavior give to an individual (or group) when compared to the absence of the behavior?" We would hypothesize that musical behavior in humans might have similar evolutionary function to other forms of social communication in animals. We conjecture that music may act as a form of a Darwinian fitness signal akin to other kinds of animal communication and display; one where

individuals signal through performances that allow others to honestly assess biological fitness (i.e. energy reserves, cognitive ability, and motor skills ...aka 'good genes' models) when making choices regarding potential mates and/or group inclusion. While modern music obviously does not always serve this function in present times, it may still contain ancestral elements of fitness signaling from the deep evolutionary past. In our preliminary work, we show that autocorrelative features defining music from other natural sounds exhibit feature shifts indicating that musicality in the human voice may have predated the evolution of speech and language. This work is preprinted at the link below, and will probably be under journal review at the time of this proposal (Babbitt et al., 2025).

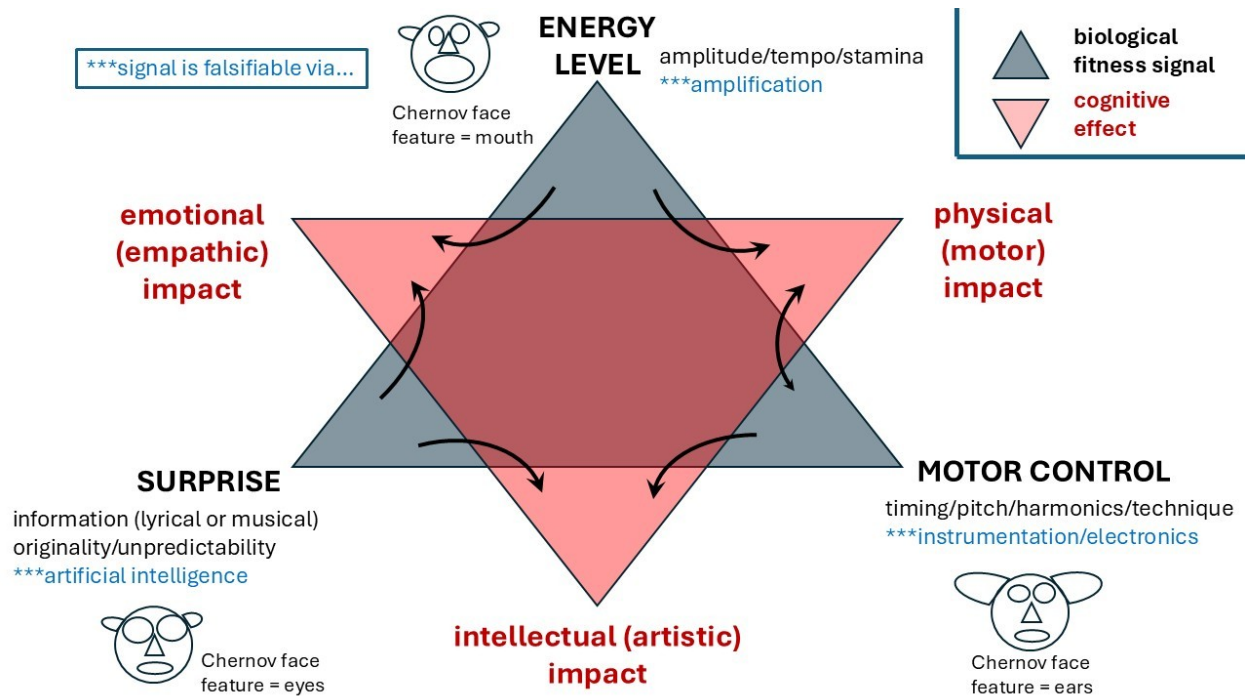
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What are the main components of fitness signaling in music? ...and what is the cognitive impact on the mind?

We put forth a geometric theoretical model for the relationship between three major axes of fitness signaling and three major cognitive effects of music (Figure 1). In animal communication, behavioral signals of fitness often evolve towards multivariate structure to promote honest signaling. For example, female birds assessing male song will often attune to several acoustic components at once, such as loudness, bout frequency, and control of species-specific elements in the song, as the combination of these elements produces a far less cheatable signal of male fitness than any single element alone. In musical sound generation as well as human physical movements in response to music (i.e. dance), we theorize that elements of fitness are combined along three major axes; energy level, motor control, and surprise (Figure 1 – upright gray triangle). Behavioral elements evolving under all of these axes would provide clear selective advantages in individual and group conflicts (i.e. in the context of individual fights or physical battles between social groups). Different combinations of emphasis on these axes of fitness create adjacent cognitive effects related to the stimulation of emotional, physical, and intellectual impacts on the mind (Figure 1 – inverse red triangle). Interestingly, the general feelings invoked by various music genres would seem to be easily explained by this basic geometry via either singular or binary emphasis on the different points of the gray fitness triangle (Figure 2).

Our proposed work will attempt to isolate acoustic features that represent the three axes of fitness signaling in music and then statistically validate the proposed model. Over summer of 2025, we will develop a python/R code base to extract mathematical acoustic features of fitness and we will apply structural equation modeling and confirmatory factor analysis (SEM and CFA) to validate the model. We plan to build upon sound extraction and post processing techniques developed for analysis of bird song (Jarne, 2019; Sawant et al., 2022) as well as statistical analysis developed from Large Language Models (LLM) to extract potentially important fitness features from audio sound files and lyrics. We plan to develop methods of assessing machine learning classification of

musical genre based upon these features. Finally, upon adequate model validation, we plan to conduct comparative analysis of experts vs. novices in both the context of human musical performance and avian bird song (in the latter using age as a proxy for experience). Initial data will be collected from YouTube and potentially other public sources (e.g. Cornell Laboratory of Ornithology).



**Figure 1. A geometric theory for the proximate stimulus and ultimate effects of musical stimulation on human minds.** Proximate stimulation is a biological signal of fitness, much like signaling in animal communication. Three components of biological fitness are energy level, motor control, and surprise or novelty. For example, a female bird might choose among prospective males based upon how loud or fast the sing (indicator of energy), how well they conform to a species-specific call (indicator of motor control), and in some species such as mockingbirds, nightingales, and lyrebirds, how well they can learn to improvise (indicator of cognitive reserve). These three outward aspects of biological fitness signaling by an individual musician or group of musicians (upright gray triangle) combine to affect the minds of performers and listeners by stimulating physical, emotional, and intellectual sensations (inverted red triangle). We also include a plan for general Chernov face representation of each potential multivariate input feature for the fitness signal when measured in various sound files. (Chernoff, 1973).

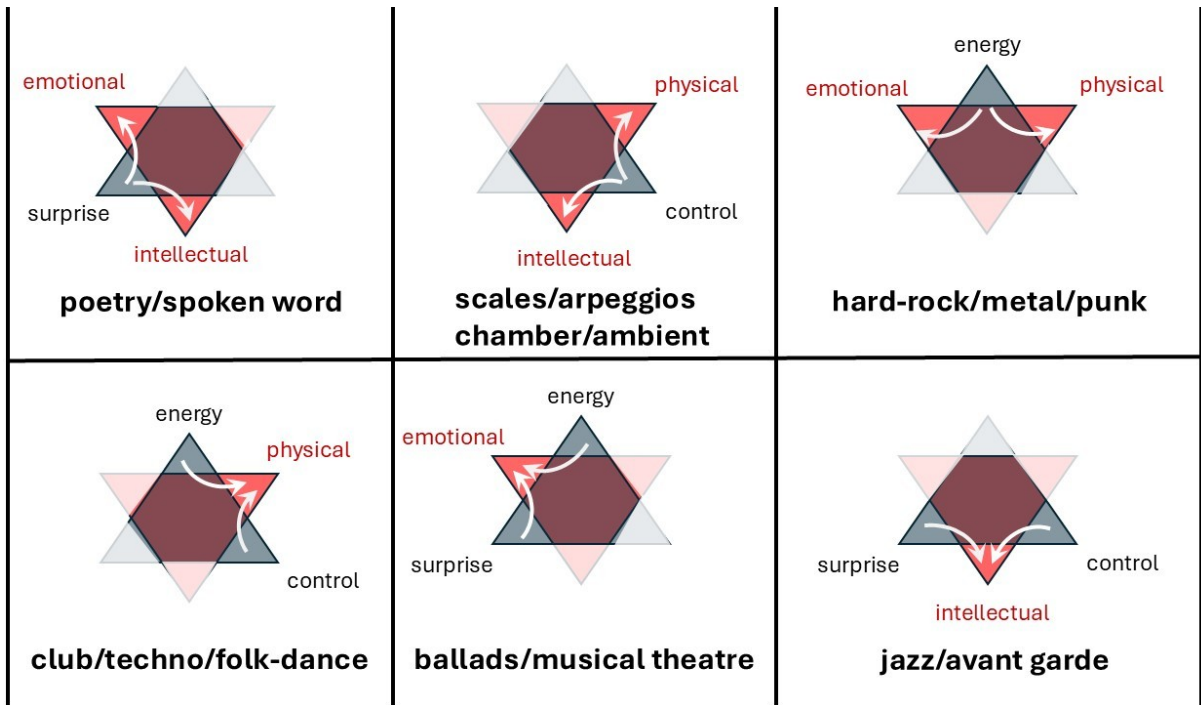


Figure 2. The effects of increased emphasis on one or two proximate stimuli (gray) can explain the cognitive reactions (red) to various artistic genres through their adjacency in the geometric pattern. For example, emphasis on just energy level in music with de-emphasis on novelty/surprise and fine motor control can result in the strong feelings of physical plus emotional impact that we often tend to associate with heavy metal/punk rock. Similarly, a singular emphasis on motor control produces a consequent lack of emotion when we listen to scales or arpeggios, and a singular focus on lyrical novelty, without emphasis energy or motor control explains the cognitive differences we perceive when comparing poetry/spoken word versus music itself. When adjacent pairs of fitness signals are emphasized in combination, it has the effect of focusing on the cognitive impact in a single area. For example, the primarily physical impact we hear in dance music is created by a combination of balanced emphasis on energy level and motor control, with little novelty or surprise. Similarly, the intellectual stimulation of jazz is created by the balanced combination of improvisation (surprise) with motor control. And the enhanced emotional impact of song ballads and musical theatre are caused by the balance of energy level and unexpected features in the lyrical or musical elements. Note; not pictured here, classical and popular music would seem to be well balanced between all three stimuli (energy, control and surprise).

## References

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