Realtime Dynamic Expressive Tuning: Where Does the Music Go?

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If the fog of equal temperament has obscured the sunshine of melody for 200 years, for so much music, (except of that of Debussy, where the fog often is intrinsic to the music), then we may welcome the power of the computer to effortlessly automatically remove it throughout. Its easy, if subtle, mathematics now joins the three other mathematical principles or laws which we have pursued for a number of decades, which aid the intimate expressive communicating function of music [5, 6].

The mathematical contradiction between the pure octave and pure fifth intervals had been known by ancient Chinese, and later independently by Pythagoras, as a simple consequence of $(3/2)^{12}$ not being equal to (2^7). The Procrustes-bed like situation could be handled quite well as long as music did not need to modulate into different keys. It then did not need to be retuned between pieces (even J.S. Bach took a record time of fifteen minutes to tune his harpsichord). The Well Tempered Clavier, earlier thought to be as Equal Temperament, turned out to be even more remarkable than was known: Bach used a tuning system developed by his friend Andreas Werckmeister, favoring certain keys over others, (instead of an 'average' as done later by equal temperament), and was able to design his pieces to be in keys more harmonious or less so, depending on the character of the music; he composed in keys taking advantage of their unequally harsh tuning.

Other static tuning systems which preserved both fifths and octaves inviolate were, in addition to Pythagoras', Meantone, Just Intonation and a slew of others. All these static systems chose variously different thirds and sixths, intervals that in the mind would accommodate various sizes more readily. Efforts were made to construct keyboard instruments with as many as 35 keys per octave to provide well sounding possibilities within an octave [8].

For the last 200 years or so to avoid this we have been used to the so called equal temperament as a static compromise to avoid this, in which, for keyboard instruments, (and computers and synthesizers) all the intervals of fifths have all been flattened by two cents (1 cent = 100th of a semitone) – and consequently all the fourths are 2 cents sharp – octaves are allowed to be pure.(Note: piano tuners find it desirable, as a nonlinear perception-based emendation 'to taste', to tune using in an 'S' curve, so that the highest and the lowest tones are somewhat sharp and flat respectively). All semitones are the same size. This ensures that from the point of view of tuning, there are no favored keys. They are all compromised.

But even the old static Werckmeister system was not really adequate for the needs. What are they? It is really brain function that determines this.

Ideally, melodies should be possible to be mined for their expressive ability, their fullest and 'natural' capacity for meaning. Tuning is a necessary, if, by itself, insufficient way towards this, involving implicit harmony and harmonic progression implied in sequential notes. The (positive or negative) increments for each sequential interval rescuing the music from the pallid equal temperament through dynamic tuning are small, but significant; its message is "to where does the music go?" i.e. it involves comparative memory. The foundation in brain function for this significance remains to be explored. It is clear that quite remarkable and little studied memory abilities are involved, to enable the brain to keep orienting itself so acutely. Here we report a solution that is empirical in nature. It is made possible by the help of the computer's ability to produce rapidly, accurately, and repeatedly, the smallest interval increments, down to a resolution of a fraction of a cent, 1/100 of one cent, i.e. 1/10,000 of a semitone. Equally important is to distinguish small changes in pitches of intervals (of successive tones) by 'ear'.

A surprising discovery was made: the same size dynamic interval requires a different increment ascending and descending (static tuning increments do not differentiate between pitch sequence, ascending or descending).

Table 1 gives the increments to equal-temperament to apply, for the intervals of successive tones. There are 12 ascending intervals, and 12 descending, making 24 increment choices. Additionally, since the increments are quite small, a choice is possible between applying the increment negatively to the first note of the interval, or positively to the second note. This makes 48 possibilities from which the computer parses. But this is an insignificant, automatic load for the computer. And because the increments are relative to equal temperament intervals, the effect is, importantly, not cumulative. The tuning is dynamic, and to a degree predictive, as contrasted with the prevalent static tunings. The same note will have a somewhat different pitch, importantly, depending on its forward context.

The pioneering work of Pablo Casals clarified much of the needs of expressive intonation. Much of this teaching is documented in the extensive series of Master Classes held and video recorded at Hertz Hall of University of California, in 1962 [1] – participants were asked to sharpen or flatten certain notes within their performance, invariably to music's benefit. How much to sharpen or flatten those tones was left to 'the ear' i.e. the brain. No quantitative guidance existed then, nor is available now. It was and is left to feeling to determine this.

When modifications were required both by static and dynamic relationships Casals mostly chose the dynamic, as preference, e.g. with regard to piano accompaniment, or also in chambermusic: the melody reigns. So the voices are mostly pitched independently.

The values of increments given here are the result of three months of intensive computer listening. It was gratifying as well as surprising that a 'pianist's ear' could have the resolve and the resolution to keep on refining these values, in an unexplored territory, but credit should well go to the computer, which alone made this possible.

TABLE I. TUNING INCREMENTS TO CONVERT EQUAL TEMPERAMENT INTERVALS TO EXPRESSIVE INTONATION (CENTS).

Interval	Up	Down
1	- .0858	+ .0440
2	+.0900	- .0123
3	+.0320	+.0730
4	+.0350	+.0440
5	+.0380	-.0450
6	-.0300	+.0430
7	+.0250	+.0410
8	+.0280	+.0400
9	+.0390	+.0350
10	-.0330	+.0360
11	.0000	.0000
12	+.0410	+.0410

Casals taught that for faster tempi increments ought to be increased (e.g. in semitone trills the trill becomes narrower when faster), and this can be adjustably embodied. This aspect too is of special neuroscientific interest.

Dynamic tuning (performances with and without), is demonstrated in Mozart's Quartet for piano and strings K478, and if time permits, other examples, from Papa Bach to Pop Music.

Note that the piano, normally inflexible tuningwise, readily participates in this tuning. If the music modulates to different keys, the tuning, too, follows, because the new key, of course, employs like intervals. No retuning is needed. The tuning is applicable also to MIDI files, classical or pop music – not for loud hard rock music, where it is irrelevant. It can be readily adapted for improvisation with electronic keyboards.

For improvisation, the information for the next note is given by a simple almost instantaneous trick signal given by the key itself, as it begins to move, before a sound is generated, a function that is easily incorporated.

(Note: this should not be used, when improvising, for predictive amplitude shaping, which properly requires knowledge of the duration of the new note as well as its pitch).

APPLYING THESE FINDINGS TO FUTURE MUSIC AND VIDEO CREATION

Invention is directed at the future: The possibilities in sound have been explored well by great composers within the technical confines available to them. Can we anticipate some of the vistas that are opening? How are principles and laws we now know projecting to the future? What may we expect to be in the offing?

This author has ventured into that world with some trepidation, with new expected and unexpected results, in various ways: cyborg, [4] and now cyborgology have become entities of their own in the fabric of society.

The above findings on music, in sum, add to the translation of the 'brainwashing black dots' on paper into living realities – of the essence of music, removing the brainwashing - and especially to the unity of a work, the coherent meaningful flow of the music from beginning to end, as Aristotle had posited long ago. It combines the story aspect of music with expressing the identity of the storyteller.

That function may be well preserved, questioned, used, and if possible enhanced in future creations of minds whose freedom is guided in new ways, opened up by each joyful and often reluctant advance. It also has its own unifying function. Phrases and themes with this intonation tend to provide a unifying framework that helps to orient the listener, to feel at home, solidify the experience: it is valuable and helpful toward the unity of a work.

And if in the act of tuning we mean to remove what is not in tune, this is in accord with the work of a sculptor who needs 'only' to remove that which is not necessary. Art, perhaps. Static tuning has fallen short for the needs of most music. And when a note returns to where it came from it may now to be seen to have a new message subtly telling us where it has been.

ACKNOWLEDGMENT

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Music Examples: Twinkle, J.S. Bach Cello Suite No 5, Mozart Quartet for Piano and Strings K483, Brahms Violin Concerto.

Twinkle without Tuning

Twinkle with tuning

Bach Cello Suite without tuning

Bach Cello Suite with tuning

Mozart K478 mvt3 with tuning

Mozart K478 mvt3 without tuning

Brahms violin concerto