Innovation
2024, Vol. 5, No. 3, pp. 83-89
https://doi.org/10.11648/j.innov.20240503.11

Research Article

A New Music Composition Technique Using Natural Science Data

Joungmin Lee*

School of Music, Ohio State University, Columbus, United States

Abstract

The relationship of music and mathematics are well documented since the time of ancient Greece, and this relationship is evidenced in the mathematical or quasi-mathematical nature of compositional approaches by composers such as Xenakis, Schoenberg, Charles Dodge, and composers who employ computer-assisted-composition techniques in their work. This study is an attempt to create a composition with data collected over the course 32 years from melting glaciers in seven areas in Greenland, and at the same time produce a work that is expressive and expands my compositional palette. To begin with, numeric values from data were rounded to four-digits and converted into frequencies in Hz. Moreover, the other data are rounded to two-digit values that determine note durations. Using these transformations, a prototype composition was developed, with data from each of the seven Greenland-glacier areas used to compose individual instrument parts in a septet. The composition *Contrast and Conflict* is a pilot study based on 20 data sets. Serves as a practical example of the methods the author used to develop and transform data. One of the author's significant findings is that data analysis, albeit sometimes painful and time-consuming, reduced his overall composing time. The variety and richness of data that exists from all academic areas and disciplines conceivably provide a rich reservoir of material from which to fashion compositions. As more composers explore this avenue of work, different methodologies will develop, and the value of works produced by this method will be evaluated.

Keywords

Music Composition, Data-Driven Method, Natural Science Data, Art

1. Introduction

To begin with, numeric values from data were rounded to four-digits and converted into frequencies in Hz. Moreover, the other data are rounded to two-digit values that determine note durations. Using these transformations, a prototype composition was developed, with data from each of the seven Greenland-glacier areas used to compose individual instrument parts in a septet [1, 5, 8, 9, 17].

The composition *Contrast and Conflict* is a pilot study based on 20 data sets. Serves as a practical example of the methods the author used to develop and transform data. One of the author's significant findings is that data analysis, albeit sometimes painful and time-consuming, reduced his overall composing time. The variety and richness of data that exists from all academic areas and disciplines conceivably provide a rich reservoir of material from which to fashion compositions [4]. As more composers explore this avenue of work, different methodologies will develop, and the value of works produced by this method will be evaluated [3].

*Corresponding author: joungminlee@joungminlee-composer.com (Joungmin Lee)

Received: 28 October 2023; **Accepted:** 9 January 2024; **Published:** 31 July 2024

2. Purpose

This paper is an attempt to shed light on a new data-driven method of music composition to enhance the scope of musical creativity and productivity.

3. Method

3.1. Overview - Data Analysis

Central to data analysis is the length of notes. The longer the note, the shorter the numbers become. A quarter note is longer than an eighth-note although four is less than eight. All these complicate the analysis process. Therefore, it is needed to assess in a retroactive way, showing that the numbers in data are in line with the length of notes [6].

However, this method can only be used when the length of notes and the numbers in data do not correspond with each other. Namely, the number 16 is identical to a 16th note. The number 32 is similar to a 32nd note.

3.2. Data for Helheim Area

Let us put these into a spreadsheet:

1) Column A: Represents time.

2) Column B: Represents velocity (m/yr).

3) Column C: Represents daily changes in satellite images.

The numbers in these columns are too detailed to be relevant (Table 1 a). The numbers have to be rounded out after the decimal point (Table 1 b). Meanwhile, Column A shows numbers that register little change in length. It is difficult to convert into music, unless otherwise into a quiet, tranquil composition.

Let us look at Column B (Table 1 b). Compared with Column A, Column B fluctuates in numbers within the audible range of frequency (20h-20kh). These numbers are appropriate to convert into melody. However, some numbers are in the higher range of audibility. The highest frequency of the piano is 4186.00, compared with 4858 in the first row of Column B. However, the harmonics of the violin can accommodate this number. The following table shows the approximate values measured in piano keys.

Table 1. *a: Value before round-off, b: Value after post-decimal point round-off.*

a

	A	B	C
1	725089.562	4858.19877	31.9999306
2	725106.558	5834.75636	15.9999421
3	725129.562	4757.69794	47.9998495
4	725129.563	4815.48023	47.9998495
5	725138.558	4498.91418	47.9998843
6	725161.563	5008.25345	15.9999884
7	725166.06	5442.73808	24.9956829
8	725166.06	6416.53886	7.00428241
9	725170.558	6201.2257	15.9999769
10	725174.06	6442.4183	8.99569444
11	725176.567	4984.5126	31.999919
12	725177.562	5139.39887	47.9998727
13	725177.563	5166.94794	47.9998727
14	725178.558	5068.98451	31.9999074
15	725182.06	4676.20272	24.995625
16	725184.567	5317.83911	47.9998495
17	725186.558	4077.92379	15.9999306
18	725190.06	4477.67241	23.0041898
19	725197.064	5297.60197	8.9956713
20	725200.566	5588.51861	15.9999306

b

	A	B	C
1	725090	4858	32
2	725107	5835	16
3	725130	4758	48
4	725130	4815	48
5	725139	4499	48
6	725162	5008	16
7	725166	5443	25
8	725166	6417	7
9	725171	6201	16
10	725174	6442	9
11	725177	4985	32
12	725178	5139	48
13	725178	5167	48
14	725179	5069	32
15	725182	4676	25
16	725185	5318	48
17	725187	4078	16
18	725190	4478	23

	A	B	C
19	725197	5298	9
20	725201	5589	16

The first row of Column B shows 4858, which is approximate to D#/Eb8, 4987.032. The first row of Column B matches D#/Eb8. The value of the second row is 5835, approximate to F#/Gb8, 5919.911.

The first 20 rows of Column B can be showing as the following:

Table 2. Frequency to musical note convert.

	Column B	Frequency	Note	Offset cents
1	4858	4978.032	D#8	-42.25
2	5835	5919.911	F#8	-25
3	4758	4698.636	D 8	21.73
4	4815	4698.636	D 8	42.35
5	4499	4434.922	C#8	24.83
6	5008	4978.032	D#8	10.39
7	5443	5587.652	F 8	-45.40
8	6417	6271.927	G 8	39.59
9	6201	6271.927	G 8	-19.68
10	6442	6271.927	G 8	46.32
11	4985	4978.032	D#8	2.42
12	5139	5274.041	E 8	-44.90
13	5167	5274.041	E 8	-35.49
14	5069	4978.032	D#8	31.35
15	4676	4698.636	D 8	-8.35
16	5318	5274.041	E 8	14.37
17	4078	4186.009	C 8	-45.25
18	4478	4434.922	C#8	16.73
19	5298	5274.041	E 8	7.84
20	5589	5587.652	F 8	0.41

Table 2 shows a frequency range of C8-G8 that can produce a melody be expressed by the violin. It should be noted that this is a resource for the melody, not the melody itself. The numbers in Column C are smaller than Columns A and B (Table 1). These values can be converted into notes and length of the note. The first two rows of Column C are identical to 32nd and 16th notes. The third row has 48, which cannot be expressed with a musical note. However, 48 can break down to 32 plus 16. Accordingly, 48 can assign to a 𝅘𝅥𝅰.or 𝅘𝅥𝅯.

The 7th row of Column C has 25, which is bigger than 16 and smaller than 32. Also, 25 can break down to 16 plus 9. The number 16 can be converted into a 16th note. In turn, 9 can break down to 8 plus 1. The number 16 can be converted into two 8th notes (𝅘𝅥𝅯). Since none can assign to 1, the composer arbitrarily assigns a note to it. Therefore, 1 is assigned to a 32nd note and a half. And hence: 1= a 64th note (𝅘𝅥𝅱). To recap, 25= 𝅘𝅥𝅯 + 𝅘𝅥𝅱 or 𝅘𝅥𝅯...

The eighth row has 7, which can break down to 4 plus 3 or a 4th note (♩) plus 3. The 3 can be three-fourths or ♪.. Accordingly, the number 7 can be expressed in ♩ + ♪.. However, it should be written as ♩...

Finally, the tenth row has 9 or 8 plus one, which is ♪ + 1. The number 1 can be converted into 1/8 (0.125). The value of 0.125 is too short to convert into a musical note. For extending the length, 9 can be converted into ♪ + 𝅘𝅥𝅱. The 18th row shows 23, or 16 (𝅘𝅥𝅯) + 7. The 16 can halve as two 8s. The remainder, 7 can approximately turn into a 16th note (𝅘𝅥𝅯) and 23 (𝅘𝅥𝅯.).

Table 3. Length of notes for Helheim area.

Data ‘C’	7	9	16	23	25	32	48
Notes	♩..	♪ + 𝅘𝅥𝅱	𝅘𝅥𝅯	𝅘𝅥𝅯.	𝅘𝅥𝅯..	𝅘𝅥𝅰	𝅘𝅥𝅰.

The spreadsheet of data of Helheim shows a total of 863 values. In Column C, the numbers can be enumerated as the following: 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 22, 23, 24, 25, 26, 27, 31, 32, and 48. Out of the 863, 19 values are overlapping, which is so small enough to convert into musical notes.

As a result of the pitch and length can be organized as the following:

Table 4. Result of the pitch and length.

	B	C	Note	Lengths
1	4858	32	D#8	𝅘𝅥𝅰
2	5835	16	F#8	𝅘𝅥𝅯
3	4758	48	D 8	𝅘𝅥𝅰.
4	4815	48	D 8	𝅘𝅥𝅰.
5	4499	48	C#8	𝅘𝅥𝅰.
6	5008	16	D#8	𝅘𝅥𝅯

	B	C	Note	Lengths
7	5443	25	F 8	𝅘𝅥𝅰..
8	6417	7	G 8	𝅘𝅥..
9	6201	16	G 8	𝅘𝅥𝅯
10	6442	9	G 8	𝅘𝅥𝅮 + 𝅘𝅥𝅱
11	4985	32	D#8	𝅘𝅥𝅱
12	5139	48	E 8	𝅘𝅥𝅱.
13	5167	48	E 8	𝅘𝅥𝅱.
14	5069	32	D#8	𝅘𝅥𝅰
15	4676	25	D 8	𝅘𝅥𝅰..
16	5318	48	E 8	𝅘𝅥𝅱.
17	4078	16	C 8	𝅘𝅥𝅯
18	4478	23	C#8	𝅘𝅥𝅯.
19	5298	9	E 8	𝅘𝅥𝅮 + 𝅘𝅥𝅱
20	5589	16	F 8	𝅘𝅥𝅯

4. Discussion

So far, methods to compose contemporary music pieces with scientific data have been surveyed, which can lay out the following points.

4.1. Enharmonicity and the Autonomy of the Octave

Column B translated into Hz to better facilitate the conversion of the values into musical notes. The conversion is based on the proximity between frequency levels and musical values, with the composers' latitude over approximate conversion. The same metrics can be applied to octave conversions. Without adjustment for the octave, some high frequencies exceed the frequency range of the instrument in question. With the adjustment, the composer will have a broader range of frequency and instrumental choices [14, 16, 19].

4.2. Atonal (in C)

Data-driven compositions do not produce keys or scores for transposition instruments. The only instrument discussed in this paper is Clarinet in Bb. Usually, for transposition instruments, a score is produced, with M2 higher. However, by incorporating atonality, all instruments can be performed without a part score.

4.3. The Length of Notes

The length can be converted or arbitrarily determined. For instance, 55 can translate into x + y or a combined eighth note.

In this paper, simplified numbers are used to determine the lengths. However, the method should improve to better determine the length or the inverse relations between the length of a musical note and the value of data [19].

5. Composition, "*Contrast & Conflict*" for Flute, Oboe, Clarinet, Bassoon, Violin, Cello and Piano

The data as mentioned earlier will be used to compose a contemporary music piece, 'Contract & Conflict,' for flute, oboe, clarinet, bassoon, violin, cello, and piano. This atonal piece consists of 20 notes, with a variety of arbitrary articulations. In this way, artistic aspects remain intact while the work is basing on scientific data.

The final goal of this paper, data-driven music composition, has culminated in the following points.

5.1. Autonomy of the Octave

Each data set has its characteristics and patterns. However, data of melting glaciers are grounded in pitches and have relatively high-frequency levels. Unmodified, these frequencies will limit the kinds of instruments to be played because only high-frequency instruments can play the composition. This raises the need for the downward adjustment of frequencies because high-frequency instruments can exclusively play music. As for the composition in question, the octave was lowered to accommodate low-frequency instruments, with the pitch unchanged [13, 15, 23].

5.2. Repetitive High-Pitch Sound

There are incidences where an instrument repeats the same sound, based or not on the composer's intention. However, such repetitiveness can be effectively mitigated by adjusting the octave downward or upward [10, 19].

5.3. Enharmonicity as Cure for Monotony

When data registers little fluctuation, it will lead to interrupted, repetitive sound patterns. The enharmonic equivalent can remedy this monotony [23].

5.4. Use of Complex Rhythms

Much of the data in question translates into complex musical notes. By tying them together, the sound can be streamlined. Also, increasing to upbeat from downbeat will make the sound more performable. Assignment of two alternate notes to a data point also streamlines the sound (for example, 𝅘𝅥𝅯 + ♩.. or ♩. + 𝅘𝅥𝅯..), not out of proportion of the analysis of data.

5.5. Performance Levels

Data-driven compositions are complex, even given the fact that they are part of modern music. This can be a severe weakness in terms of a possible performance of them. Finding musicians capable of playing such compositions will be not easy. After a series of practice and rehearsals, a conductor will be needed to facilitate performances by an ensemble or a trio. Alternatively, they can practice in conjunction with MP3 recordings, video clips or metronome.

5.6. Shortening Composition Time

As data analysis led to spreadsheets of sound lengths and pitches, it has become self-evident that time spent on composition has shortened substantially. The placement of musical notes has already been done, leaving the composer with previously time-consuming jobs of articulating and placing rests. The overall perspective and instrumental harmony have yet to be taken care of, but composition time has shortened.

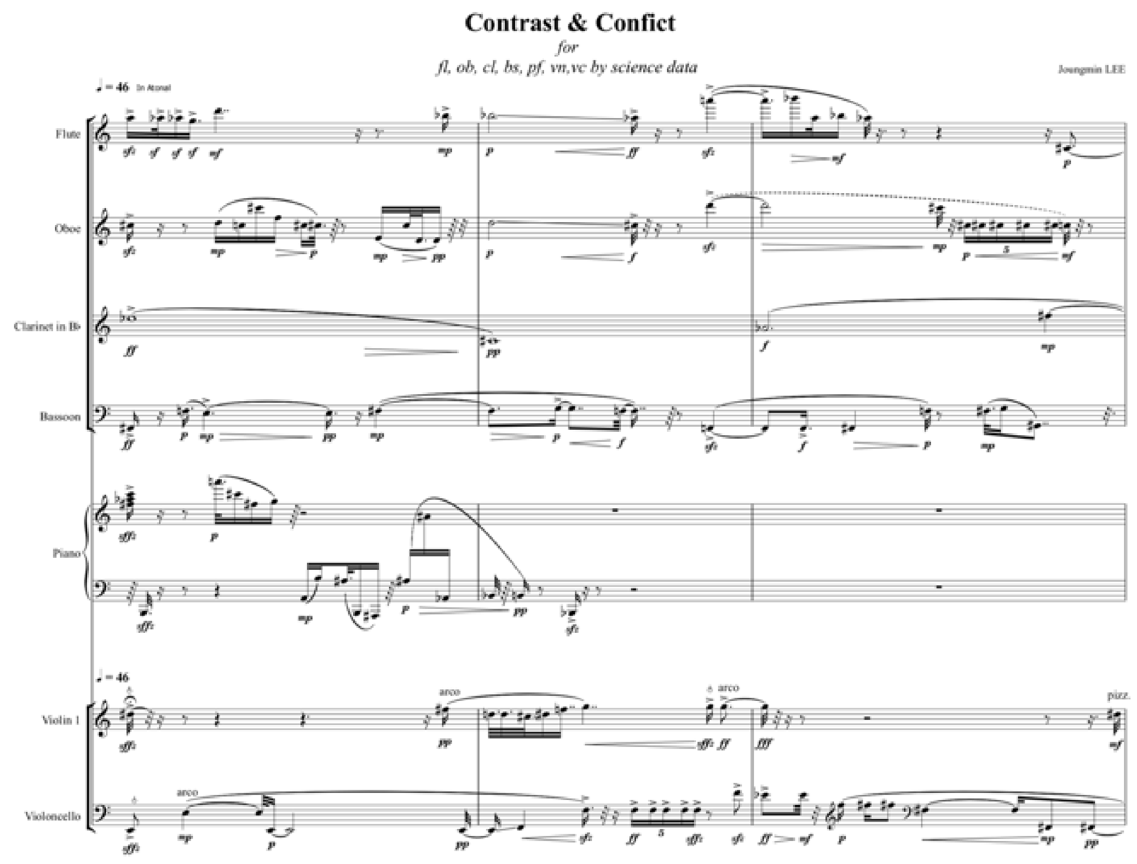
The primary factor that shortens time lies with the fact that there is an increasing overlapping in data as the analysis was proceeded with. While it varies depending on data sets, the pitches and lengths of sound can turn into tempo, rhythms, rests, and articulations—or a repeat of these. There is a reasonable likelihood of shortened composition time [23].

5.7. Lquidity of Data Analysis

Analysis of data can turn up multiple probable values. For instance, 7 and 8 can turn into 4 (♩) + 3 (♪.) = ♩.. and 8 = ♪, threefold of 7. Basically, 7 should be at least less than 𝅘𝅥𝅯 which is less than ♪. To express 7 in lower notes than ones in which 8 is expressed, it would take more complex calculations—the process that will likely yield hundreds of notes. It will be excessively time-consuming. All these calls for the need for data liquidity. To inject personal philosophy and view into the composition, the composer needs to have consistency in data analysis [7, 19, 23].

5.8. Philosophy

As discussed briefly above, the composer needs their philosophy. They need to think ahead to determine commonality and relatedness between data and their composition style; the subject matter to give expression to; their expectations in the composition; ways to inject their philosophy and ideas; and their audiences and appeal [12, 18, 20-22].



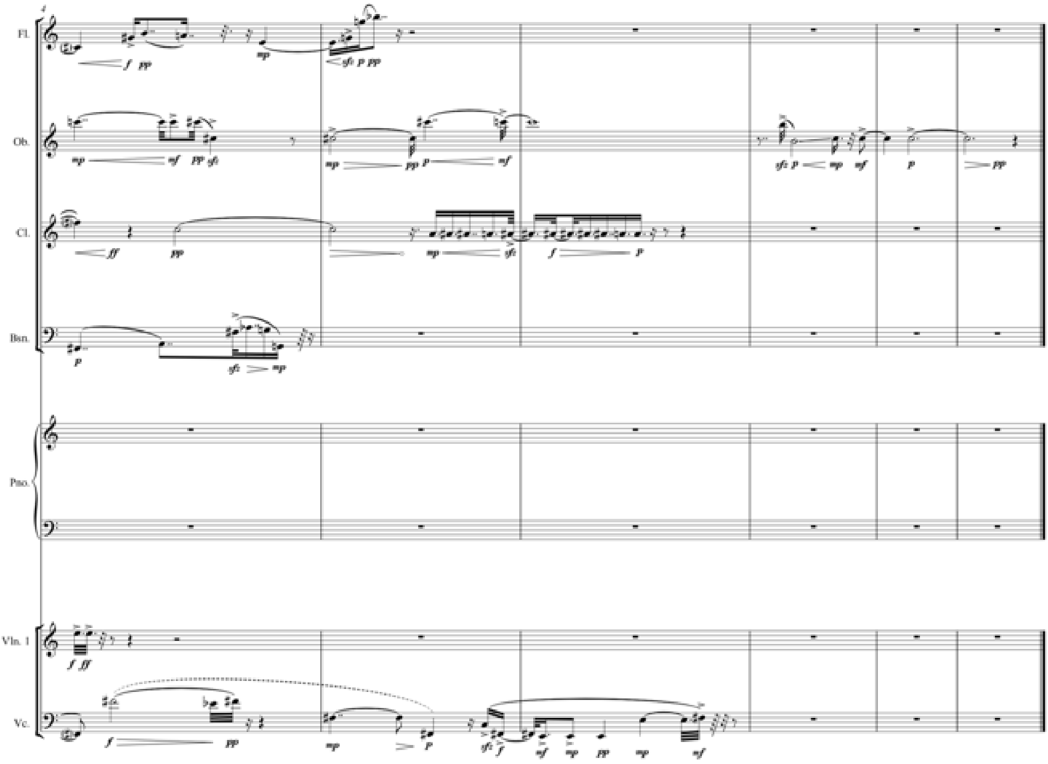


Figure 1. *A full score, "Contrast & Conflict.*

6. Conclusions

This paper has examined new compositional methods using scientific data in an attempt to shed light on a new data-driven method of music composition to enhance the scope of musical creativity and productivity. It also created a spreadsheet of the heights and lengths of sound coming from the data of melting glaciers to compose pieces of musical work for seven instruments [2].

The most important finding was the ability of such a method to shorten composition time. The number of notes for an instrument was limited to 20 (some instruments need more than 20 because rhythms need splitting as dictated by data analysis). Without data analysis, it would have taken three or four days to compose a piece of such complexity. This composition period includes drafting, instrumental composition, conceptualization, and philosophical founding. Even with more musical notes and essential work needed, the data-driven composition will be more time-saving than traditional methods. Of course, data collection and analysis can be time-consuming. Transformation of data into musical notes can be more timing-consuming than usual preparations for music composition. Once all in spreadsheets, the process will be substantially more timesaving [11].

The above finding is conspicuous, and what is more important is: an entirely single method used for composition. Electronic music pieces inspired by glacier data does not represent a leap in music or creativity. However, the acoustic piece presented in the paper epitomized in what future-oriented modern music is about: technique, complexity, creativity and musical values. It also offered an opportunity to unlock unlimited potential because it showed the possibility of developing uniqueness by using any data.

However, the complexity of the composition may diminish the opportunity for it to perform. More research is needed to substitute complex pitches or acoustic lengths with alternatives such as rests and articulations.

Author Contributions

Joungmin Lee is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] A. Koblyakova, S. Petoukhov, I. Stepanian, The Genetic Code, the Golden Section and Genetic Music, The Moscow PI. Tchaikovsky Conservatory, 2015.

[2] Catherine Schmidt-Jones, Sound, Physics and Music, Online: http://cnx.org/content/col10261/1.1/ Rice University, Houston, Texas, 2005.

[3] Christopher Dobrian, Realtime Stochastic Decision Making for Music Composition and Improvisation, 1966.

[4] David J Hargreaves, Dorothy Miell, and RAYMOND A. R. MACDONALD, What are musical identities, and why are they important, Article, January 2002.

[5] David R. Lapp, The Physics of Music and Musical Instruments, Wright Center for Innovative Science Education, Tufts University, 2003.

[6] Frans Absil, A Guide to Schillinger’s Theory of Rhythm Second Edition, F. G. J. Absil, the Netherlands, 2015.

[7] Ian Cross, Music and science: three views, University of Cambridge, 1998.

[8] Iannis Xenakis & Additional Material compiled and edited by Sharon Kanach, Formalized Music – Thought and Mathematics in Composition, Harmonologia Series No. 6 – Pendragon Press Stuyvsant NY, 1992.

[9] James Harley, The Creative Compositional Legacy of Iannis Xenakis, School of Fine art and Music, University of Guelph, 2006.

[10] James Q. Feng, Ph.D., Music in Terms of Science, 2012.

[11] Janelle Anderson, Xenakis' Combination of Music and Mathematics, The Journal of Undergraduate Research - South Dakota State University, 2011.

[12] John Haines and Patricia DeWitt, Johannes De Grocheio and Aristotellan Natural Philosophy, Cambridge University Press, 2008.

[13] Joseph Schillinger, The Schillinger System of Musical Composition, The Musical Quarterly, Vol. 32, No 3, 1946.

[14] Leibniz, Mathematics illuminated Unit 10, Harmonious Math Textbook, 2017.

[15] Matthew Rankin, A Computer Model for the Schillinger System of Musical Composition, A thesis submitted in partial fulfillment of the degree of Bachelor of Science (Honours) at The Department of Computer Science Australian National University, 2012.

[16] MIT OpenCourseWare, 2.161 Signal Processing: Continuous and Discrete - For information about citing these materials or our Terms of Use, 2008.

[17] NASA Distributed Active Archive Center (DAAC) at NSIDC, GIMP Data (Greenland Ice Mapping Project), https://nsidc.org/data/measures/gimp

[18] Philipp Brüllmann, Music Builds Character Aristotle, Politics VIII 5, 1340a14–b5, De Gruyter, 2013.

[19] Reginald Bain, The Harmonic Series - A path to understanding musical intervals, scales, tuning and timbre, University of South Carolina, 2003.

[20] Stanford Encyclopedia of Philosophy, Enlightenment, First published Fri Aug 20, 2010; substantive revision Tue Aug 29, 2017.

[21] Stanford Encyclopedia of Philosophy, Scientific Method, First published Fri Nov 13, 2015, https://plato.stanford.edu/entries/scientific-method/

[22] Stephen Malloch and Colwyn Trevarthen, The Human Nature of Music, US National Library of Medicine National Institutes of Health Search database Search term, 2018.

[23] Stephen R Hoon (Manchester Metropolitan University) & B. K. Tanner (Durham University), The physics of music, Article in Physics Education, Phys. Educ., Vol 16. 1981 Printed In Great Britain, 1981.