THE SONIFICATION METAPHOR IN INSTRUMENTAL MUSIC AND SONIFICATION'S ROMANTIC IMPLICATIONS

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ABSTRACT

The sonification metaphor is not limited to electronic sound synthesis and computer music, but can be applied to instrumental music as well. The relation of sonification to program and experimental music is discussed and works by Iannis Xenakis, Karlheinz Stockhausen, John Cage and Alvin Lucier are briefly introduced. The paper leads to a discussion of the connection between sonification and romanticism, where the desire is to directly evoke an understanding of natural phenomena.

1. INTRODUCTION

When, after initial explorations in the 1870s [1], the concept of data sonification was established in the 1980s and further developed in the following decade [2], [3], two assumptions came to be taken for granted: First, sonification is considered a human/computer interface and hence the means of sound production are electro-acoustic, and second, sonification reveals some information about the matter represented by the sonified data. Weinberg and Thatcher even describe the latter aspect of data exploration as "immersive" and claim "a direct and intimate connection to the information" [4][1]. From a musicologist's point of view, the concept of data sonification appeals for two reasons. First, sonification as an idea released from its ties to computer applications can act as a metaphor for non-electronic compositions that are strictly representational in nature. I am referring here not so much to instances of program music that communicate a narrative, but to works in the tradition of experimental music that map extra-musical data to musical parameters. Second, the basic assumption of sonification researchers, that their technique provides a means to gain an immediate understanding of the matter represented in sound, seems to be derived from certain concepts suggested by Early Romanticism. The idea of a *Natursprache*, a poetic language in which one could directly experience nature as the embodiment of a divine being, is prominently expressed in the writings of Novalis [5][2], [6]. While there is no proof that those involved in sonification research read the late 18th century German philosophers, the proximity of their ideas might suggest a connection through common cultural knowledge.

2. PROGRAM MUSIC AND THE SONIFICATION METAPHOR

To claim that absolute music, that is, instrumental music without reference to extra-musical entities, is the paradigm of music per se, is an assertion of early 19th century music aesthetics. Vocal music obviously refers to the themes expressed in the lyrics, and instrumental music had always served social or ritual purposes. By means of tone painting, instrumental music can imitate the sounds around us, like birds, water or thunderstorms. Beethoven's statement that his Sixth Symphony, the *Pastoral Symphony*, was "mehr Ausdruck der Empfindung als Malerey" – "more the expression of feeling than painting" – marks the beginning of a conception of program music where the music does not merely convey a literary narrative through musical imitation of characteristic acoustic objects (think of Smetana's *Moldau*, for instance), but instead creates an imaginary drama or represents a poetic idea. That the extra-musical program does not need to be known to the listener is shown by Tschaikowsky's Sixth Symphony, *Pathetiqué*, where the composer preferred to keep the program to himself. This establishes an interesting double bind, since the listener knows s/he is not meant to take the work for absolute music, yet the program remains a secret. The listener is supposed to experience a meaning beyond the music, just as someone listening to sonification signals is supposed to interpret information communicated through sound.

[1] p. 9

[2] p. 147, n30

Starting in the 1950s, composers began to refer to extra-musical entities, particularly scientific data, on a different level. They no longer *imitated* sounds or expressed certain feelings or poetic ideas, but incorporated algorithmic or conceptual procedures in their compositional process. The sonification metaphor was used, before its concept was established, to map the shapes of stones or the panorama of the Alps to melodic lines or sound spectrums. This way, the representational aspect was internalized into the composition itself.

2.1. Iannis Xenakis: *Pithoprakta*

In 1955/56, Iannis Xenakis used stochastic calculations in the composition of his orchestra piece *Pithoprakta*. The speeds of the glissandi of 46 separately scored string instruments were determined by a formula describing the Brownian motion of gas particles. For a section of 18.5 sec. duration (measures 52-60), Xenakis calculated 1148 speeds, which he distributed into 58 values according to Gauss's law. A graph illustrates the movements of the pitches (fig. 1).

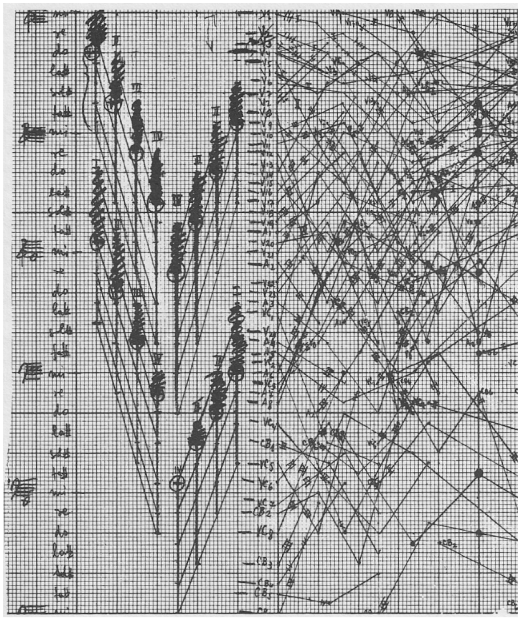

Figure 1: Iannis Xenakis, sketch for *Pithoprakta* [7][1]. Copyright © 1967 by Boosey & Hawkes Music Publishers Limited. Used by kind permission.

In each part, the durations of the glissandi remain constant, occasionally skipping one beat. The durations are 3, 4 or 5 beats per measure with 26MM (beats per minute) a measure. The three tempi superimposed create a rather complex resulting rhythm [7][2].

Since the durations of the glissandi of each instrument remain constant, the change of speed needs to be expressed by the change of interval that gets spanned within the constant duration (fig. 2). The sonified speed of the gas particles is musically represented by the glissando's differential. (The use of pizzicato, however, makes it rather difficult to actually hear the glissandi, since the attack emphasizes the pitches from which the sliding tones start).

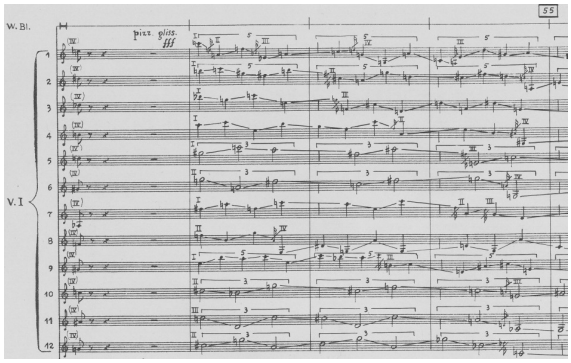

Figure 2: Iannis Xenakis, *Pithoprakta*. Violins I, measures 51-54 [8]. Copyright © 1967 by Boosey & Hawkes Music Publishers Limited. Used by kind permission.

In *Pithoprakta*, Xenakis did not actually sonify measured or otherwise observed data, but merely illustrated the mathematical description of the physical phenomenon. He called his approach "one of those 'logical poems' which the human intelligence creates in order to trap the superficial incoherencies of physical phenomena, and which can serve, on the rebound, as a point of departure for building abstract entities, and then incarnations of these entities in sound or light" [7][3]. Here, the composer limits the role of sonification to a point of departure for his inspiration. He is not so much interested in the concept of translating scientific data into musical parameters, but rather in emphasizing the connection between the arts of music and mathematics, as established by Ancient Greek philosophers and the theorists of the Middle Ages.

2.2. Karlheinz Stockhausen: *Gruppen*

In a similarly abstract way, Karlheinz Stockhausen made reference to the mountains around Paspels, Switzerland in his *Gruppen* for three orchestras. Begun in the little village in the summer of 1955 and completed two years

[1] p. 18

[2] p. 15

[3] p. 13

later, *Gruppen* demonstrates Stockhausen's serial conception of translating rhythm into timbre and vice versa by increasing and decreasing speed – an idea obviously derived from Stockhausen's experiments with tape manipulation in the electronic music studio.

In his seminal essay *…wie die Zeit vergeht…* ("how time passes" [9]), Stockhausen discussed his approach to achieving aesthetic unity by subjugating micro- and macro-time, that is timbre and rhythm, to the same compositional principles. Here, he presents a graph of a so-called group spectrum, i.e. the relation of superimposed tempi, in a very distinct shape (fig. 3). In an interview, Stockhausen revealed (almost 20 years later) that many envelopes of structural sections of *Gruppen* are precise representations of the mountain panorama he viewed from his window in Paspels [10][1].

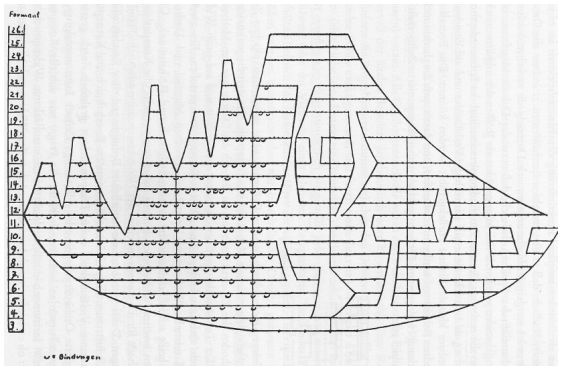

Figure 3: Karlheinz Stockhausen, sketch for *Gruppen* [9][2]. Copyright © Archiv der Stockhausen-Stiftung für Musik, Kürten (www.stockhausen.org). Used by kind permission.

Obviously, these shapes cannot be perceived by the listener. The graph controls the music on a highly abstract level and was certainly never meant to be directly experienced. Nevertheless, considering Stockhausen's metaphysical yearning for unity, and given the humor of the 27-year-old who had acted against his serial principle when he inserted a metaphorical "thunderclap" in his tape piece *Study I* (1953) on the occasion of the birth of his daughter [11][3], we witness the well-known setting of a composer establishing a hidden subtext. We might have pushed the sonification metaphor to an extreme by connecting it with a parameter mapping that resists decoding. But the composer's interest might lie not so much in communicating what s/he already knows as in creating an aesthetic situation that is open to the unknown.

3. SONIFICATION AND EXPERIMENTAL MUSIC

John Cage, one of the most prominent exponents of American experimental music, described his aesthetic concept of composition, performance and listening as being fundamentally experimental in nature, i.e. open to an unpredictable outcome or experience: "New music: new listening. Not an attempt to understand something that is being said, for, if something were being said, the sounds would be given the shapes of words" [12][4]. Here is no place for an author who expresses emotions or attitudes in music with the intention of communicating them to the listener. Instead, the composer "may give up the desire to control sound, clear his mind of music, and set about discovering means to let the sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments" [12][5].

That these means are to be *discovered* is characteristic for Cage's understanding of the creative act. Discovery and experiment are scientific procedures which Cage unhesitatingly employed in the realm of composition. To remove personal preferences, he utilized various chance techniques, most notably the Chinese oracle *I-Ching*, but also the observation of imperfections in music paper (in his *Music for Piano*, 1952-56) or the "placing of transparent templates on the pages of an astronomical atlas and transcribing the positions of stars" [13][6] (in *Atlas Eclipticalis*, 86 instrumental parts to be played in whole or part, 1961/62). What was already obvious in the use of stars in *Atlas Eclipticalis*, the notion of translating meaningful data into music and thereby establishing a programmatic subtext, became more prominent in Cage's open music theater piece *Song Books* (1970). Here, the performers are asked to map the lines of a portrait of Henry David Thoreau (*Solo for Voice 5*), the profile of Marcel Duchamp (*Solo for Voice 65*) or a certain route on the map of Concord, Mass. (*Solo for Voice 3*) to a melodic line.

Cage also used electronic means to translate physical data derived from light sensors and capacitance antennas into musical parameters that would influence a complex live-electronic sound system, as in *Variations V* (1965). There, Cage finally had available the facilities to "transform our contemporary awareness of nature's manner of operation into art" [12][7]. That same year, Alvin Lucier premiered his *Music for Solo Performer*, where enormously amplified brain waves stimulate percussion instruments, and ten years later the idea of using biofeedback in the arts was prominent enough to establish a project at the Aesthetic Research Center of Canada [14]. The rise of live-electronic music and more

[1] p. 141
[2] p. 123
[3] p. 94
[4] p. 10
[5] p. 10
[6] p. 62
[7] p. 9

easily available sensor technology in the 1960s, as well as the improvement of computer performance for algorithmic composition and sound synthesis, led to a considerable increase in the number of electronic music compositions influenced by the sonification metaphor [15], [16]. To supplement research undertaken in the field of electro-acoustic music, I will here discuss two works of instrumental music that are inspired by the sonification metaphor.

3.1. John Cage: *Ryoanji*

In 1983-85, John Cage composed *Ryoanji* in five parts for flute, oboe, trombone, voice, and double bass, to be performed solo or in any combination, but always together with a part for percussion (or orchestra in unison). The scores are graphic, consisting of curved lines that indicate glissandi with time equaling space on the horizontal and pitch equaling space on the vertical axis (fig. 4). The title *Ryoanji* refers to the Ryoanji Zen garden in Kyoto, Japan, where 15 large stones are placed in 5 groups (of 5, 2, 3, 2, and 3 stones from east to west) on a slim rectangle of raked sand. Cage created the graphs in the score by placing stones from a collection of 15 at chance-determined positions on paper and tracing parts of their perimeters. Per double page, 15 to 30 stones were used, and sometimes up to four lines overlap in one instrument, so that parts need to be pre-recorded and played back during live performance [17][1], [19].

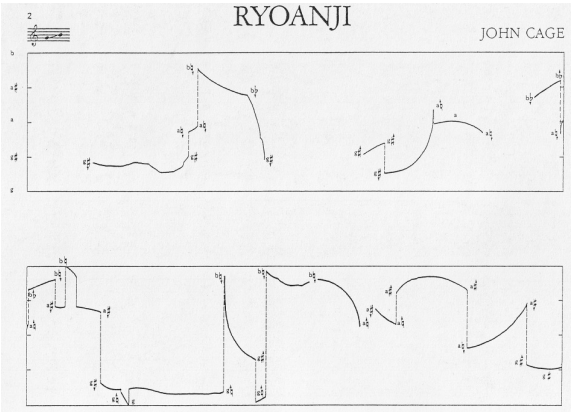

Figure 4: John Cage, *Ryoanji*. Flute [21]. Copyright © 1984 by Henmar Press Inc. Used by kind permission. All rights reserved.

(To be precise: in preparing the score, Cage actually did not draw around stones; he used paper templates that resembled the shapes of the 15 stones. This was not so much to facilitate the composition process, but to ensure that repetitions would occur: "I obviously couldn't write music with stones, because when you draw around a stone you don't necessarily draw the same way each time" [20][2].)

An important aspect in data mapping is the question of scale. The horizontal axis of the *Ryoanji* score equals time, but only the part for voice contains a tempo indication, two minutes per double page that constitute one section (or "garden"). From what we know about Cage's practice when scoring and rehearsing the first performances, we can assume the same tempo was requested for all the parts. In contrast, the scaling of the vertical axis is indicated in the scores since it changes chance-determined for every section, varying from one semitone (in the flute, pp. 6/7) to one octave and a fourth (in the voice, pp. 18/19). Obviously, the scaling factor of the pitch axis greatly impacts the sounding result. It determines whether the changes in pitch are microtonal and subtle, or large intervals are spanned in high tempo. So it comes as no surprise that Cage used this factor as a dimension of composition. By the way, musically this situation is very similar to Xenakis's transformation of particle speeds into glissandi by controlling the intervals spanned by these glissandi.

According to Cage's performance instructions, "[t]he glissandi are to be played smoothly and as much as is possible like sound events in nature rather than sounds in music" [21]. In other words, the sonification of natural objects is supposed to sound like nature, not music. But Cage's composition is not so much representational of stones he traced but of the Ryoanji garden as a whole. In his comments, Cage claims "the staves are actually the area of the garden" [20][3], and "for the accompaniment [i.e. the percussion part] I turned my attention to the raked sand" [17][4]. In summary, it may be argued that the composition *Ryoanji* is a conceptual artistic representation of the garden, incorporating elements of sonification.

Inspired by his work with magnetic tape, Cage had begun utilizing propositional notation where time equals space in the early 1950s. As he explained, "with propositional notation, you automatically produce a picture of what you hear" [20][5]. This connection of music music and visual representation can easily be turned around, so that the music follows what you see (e.g. the aforementioned music from star maps and drawings). Basically, this means nothing other than the interchangeability of visual and auditive representation, which is one of the fundamental assumptions of sonification research.

[1] pp. 134-136; also, with illustrations: [18]

[2] p. 280
[3] p. 242
[4] p. 135
[5] p. 243

3.2. Alvin Lucier: *Panorama*

In his composition *Panorama* for Trombone and Piano (1993), Alvin Lucier mapped the panorama of the Swiss Alps to the pitches of a slide trombone. He worked from a reproduction of a panorama drawing by Fritz Morach after a landscape photo by Hermann Vögeli [22]. The print (98 x 11.5 cm) indicates the mountain peaks with vertical lines that label their name and height (fig. 5).

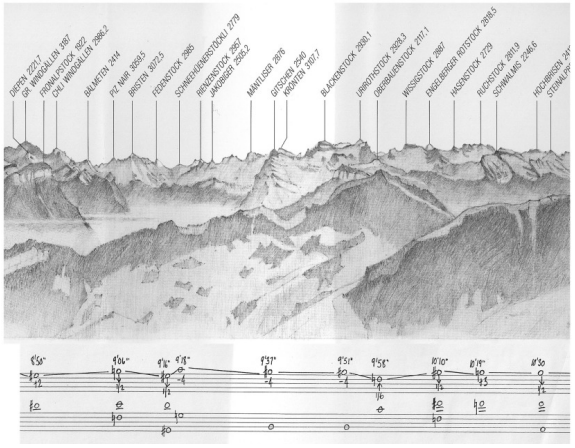

Figure 5: Alvin Lucier, Panorama. Excerpt from drawing [22] and score. Copyright © Alvin Lucier. Used by kind permission.

In his composition, Lucier kept the scaling of both dimensions fixed: The mountain height in meters divided by 8 results in the frequency in Hz, and the distance between two mountain peaks in mm is interpreted as time in seconds, leading to a total duration of 16 minutes. Since Lucier did not use a longitudinal section of the mountain range but worked from a panorama view, the distances he sonifies do not correspond to the actual distances between the peaks, a fact that is reflected in the work's title.

The piano part indicates the moments when the trombone reaches a mountain peak with a single tone or a two-tone chord of adjacent pitch classes. Since the trombone freely slides through the continuum of frequencies, while the piano is bound to pitches in equal temperament, beatings and difference tones occur. This is a typical technique Lucier has incorporated in his compositions since the 1980s.

Besides his affinity for translation processes in music and sound art, Alvin Lucier often draws his inspiration from scientific experiments. His reference to sonification satisfies both interests. It also stands for the composer's belief that his aesthetic research may reveal the beauty and charm of the world around us. He once explained that "in imitating the natural, the way the natural world works, you find out about it, and you also connect to it in a beautiful way" [23][1]. And disclosing the metaphysical implications of his aesthetic approach, Lucier stated that his works were "perhaps closer in spirit to alchemy, whose purpose was to transform base metals into pure gold" [24][2].

4. SONIFICATION'S ROMANTIC IMPLICATIONS

John Cage and many experimental music composers after him are known to have been influenced by the writings of the American Transcendentalist Henry David Thoreau. In *Walden*, an essay that reflects his experience of living alone in the woods from 1845 to 1847, Thoreau interprets the quality of sounds heard from a long distance and echoed in the valleys as "a vibration of the universal lyre" [25][3]. In 1851 Thoreau witnessed a telegraph line being erected [26][4]. Despite his doubts about the usefulness of this invention ("We are in great haste to construct a magnetic telegraph from Maine to Texas; but Maine and Texas, it may be, have nothing important to communicate." [25][5]) Thoreau enjoyed and attached importance to the sound of the "telegraph wire vibrating like an Æolian Harp" [26][6]. To Thoreau, the telegraph became "[t]he first strain of the American lyre" [27][7] and and "the divine humming of the telegraph" [27][8] revealed revealed the "spirit [that] sweeps the string of the telegraph harp – and strains of music are drawn out endlessly like the wire itself. We have no need to refer music and poetry to Greece for an origin now. […] The world is young & music is its infant voice" [26][9]. Finally, Thoreau states, the "wire […] always brings a special & general message to me from the highest" [28][10] – "the wind which was conveying a message to me from heaven dropt it on the wire of the telegraph which it vibrated as it past [sic]" [28][11]. This phrasing is indeed close to the often quoted definition of sonification as the "use of non-speech audio to convey information" [29][12].

Thoreau, however, favors the language metaphor, when he records in his journal the way he sees himself: "A writer a man writing is the scribe of all nature – he is the corn & the grass & the atmosphere writing" [26][13].

[1] p. 348
[2] p. 11
[3] p. 123 (chapter *Sounds*)
[4] p. 16 (Aug. 28, 1851)
[5] p. 52 (chapter *Economy*)
[6] p. 75 (Sept. 12, 1851)
[7] p. 3 (Feb. 13, 1854)
[8] p. 4 (Feb. 13, 1854)
[9] p. 238 (Jan. 3, 1852)
[10] p. 437 (Jan. 9, 1853)
[11] p. 76 (Sept. 12, 1851)
[12] chapter 1, *Executive Summary*
[13] p. 28 (Sept. 2, 1851)

He also claims we were "in danger of forgetting the language which all things and events speak without metaphor" [25][1].

The idea that nature implies a language that, if only understood, could reveal metaphysical entities otherwise inaccessible to mankind is prominent in German Early Romanticism of the late 18th century. Novalis, in his *Die Lehrlinge zu Saïs* ("The Novices of Sais"), compares the routes men take to wondrous figures, which seem to belong to the script of ciphers that one can behold everywhere, on wings and egg shells, in clouds, in snow, in crystals and geological formations, in filings drawn to a magnet, finally in figures created by sand on vibrating sheets [30] [2] . The latter obviously refers to the experiments of Ernst Chladni, who covered metal sheets with a thin layer of sand before he made them vibrate by means of a violin bow. Depending on the vibrations the sand would move on the surface and establish geometrical figures (fig. 6).

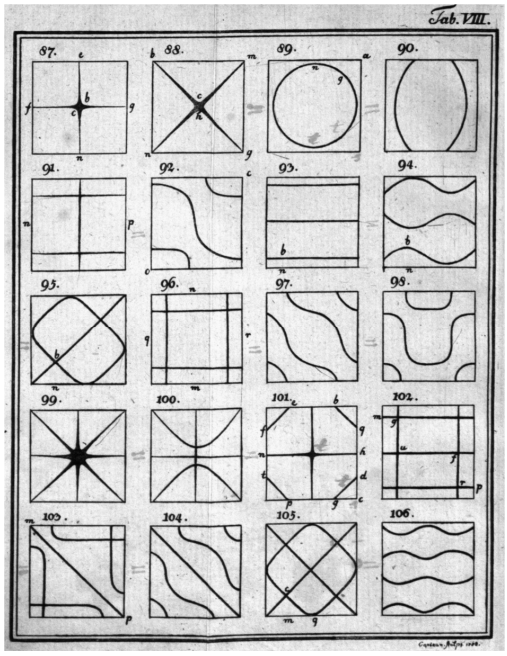

Figure 6: Chladni-Figures [31][3]

Just as Thoreau would half a century later, Novalis likened nature to an "Æolian harp, a musical instrument whose sounds are again keys to higher strings in ourselves" – a setting he calls *Ideenassociation* [association of ideas] [32] [4] . In his notes toward encyclopedism, Novalis finally asked himself whether all sculptural form, from crystal to man, could not be described acoustically, as inhibited movement. As chemical acoustics [32][5].

In their research on sonification, scholars and artists alike borrow from the romanticists' yearning to break the spell and make the world understandable by translating natural phenomena to our senses for immediate perception. Gregory Kramer opens his essential *Introduction to Auditory Display* [3] with a quote by Sufi teacher Hazrat Inayat Khan (1882-1927) from his *Mysticism of Sound and Music*: "[I]n the realm of music the wise can interpret the secret and nature of the working of the whole universe" [33][6]. In his epigraph, however, Kramer changed "music" to "sound" and thereby extended the source of inspiration from a man-made art to a physical quality as such. Similarly, Andrea Polli quotes Walt Whitman's nature poem *Proud music of the storm* when introducing her works that sonify meteorological data [34], and Chris Hayward titled a paper on the sonification of seismological data poetically – and somewhat euphemistically – *Listening to the Earth Sing* [35].

Without typecasting these and many other authors as hidden romanticists, I would like to emphasize the unspoken implication of metaphysical assumptions and romantic motives in sonification research. The recognition of these implications may not only further an understanding of the intellectual fascination with which sonification projects are received, but may also facilitate exchange between scientists and composers. The latter seems to me of prime importance if we are to improve the aesthetic and artistic quality of sonification applications and artworks.

5. ACKNOWLEDGMENTS

I would like to thank Alvin Lucier for most generously providing me access to the sketches of his *Panorama*. Thanks are also due to one of the reviewers for much appreciated detailed and constructive criticism.

[1] p. 110 (chapter *Sounds*)
[2] p. 79 (the very beginning)
[3] appendix, table VIII

[4] p. 212 (966) – "Die Natur ist eine Aeolsharfe – Sie ist ein musikal[isches] Instrument – dessen Töne wieder Tasten höherer Sayten in uns sind."
[5] p. 68 (376) – "Sollte alle plastische Bildung, vom Krystall bis auf den Menschen, nicht *acustisch*, durch gehemte Beweg[ung] zu erklären seyn. Chemische Acustik."
[6] p. 16

6. DISCOGRAPHY

J. Cage, *Ryoanji*. Therwil: hatART, CD6183, 1996. CD (Robert Black, doublebass; Eberhard Blum, flute; Iven Hausmann, trombone; Gudrun Reschke, oboe; John Patrick Thomas, voice; Jan Williams, percussion).

A. Lucier, "Panorama". *Alvin Lucier - Panorama*. New York: Lovely Music LCD1012, 1997. CD (Roland Dahinden, trombone and Hildegard Kleeb, piano).

I. Xenakis, "Pithoprakta" [p1965]. *Xenakis - Eonta, Metastasis, Pithoprakta*. [France]: Le Chant du Monde, LDC 278 368, [1986]. CD (Maurice Le Roux, conductor; Orchestre National de l'ORTF).

7. REFERENCES

[1] F. Dombois, "The 'Muscle Telephone': The Undiscovered Start of Audification in the 1870s." In *Sounds of Science - Schall im Labor (1800 - 1930)*, ed. J. Kursell, Workshop Sounds of Science, Max-Planck-Institut für Wissenschaftsgeschichte Berlin, 2006, pp. 41-45. Berlin: Max-Planck-Institut für Wissenschaftsgeschichte, 2008.

[2] S. Bly, "Presenting Information in Sound." *Conference on Human Factors in Computing Systems*, Gaithersburg, Maryland March 15-17, 1982.

[3] G. Kramer, "An Introduction to Auditory Display." In *Auditory Display. Sonification, Audification, and Auditory Interfaces*, ed. G. Kramer, Sante Fe Institute Studies in the Sciences of Complexity. Proceedings 18, pp. 1-77. Reading, MA: Addison-Wesley, 1994.

[4] G. Weinberg and T. Thatcher, "Interactive Sonification: Aesthetics, Functionality and Performance." *Leonardo Music Journal*, vol. 16, pp. 9-12, 2006.

[5] A. Stone, "Being, Knowledge, and Nature in Novalis." *Journal of the History of Philosophy*, vol. 46, no. 1, pp. 141-163, Jan. 2008.

[6] A. Goodbody, *Natursprache. Ein dichtungstheoretisches Konzept der Romantik und seine Wiederaufnahme in der modernen Naturlyrik (Novalis - Eichendorff - Lehmann - Erich)*, Kieler Studien zur deutschen Literaturgeschichte 17; Ph.D. Univ. Kiel 1983. Neumünster: Wachholtz, 1983.

[7] I. Xenakis, *Formalized Music. Thought and Mathematics in Music*. Ed. S. Kanach. Stuyvesant, NY: Pendragon, 1992.

[8] I. Xenakis, *Pithoprakta* [1956]. Score. [Bonn]: Boosey & Hawkes rental library, no year.

[9] K. Stockhausen, "...wie die Zeit vergeht..." [1956]. In *Texte zur elektronischen und instrumentalen Musik. Aufsätze 1952-1962 zur Theorie des Komponierens*, ed. D. Schnebel, Texte 1, pp. 99-139. Köln: DuMont, 1963.

[10] J. Cott, *Stockhausen. Conversations with the composer*. New York: Simon & Schuster, 1973.

[11] M. Kurtz, *Stockhausen. Eine Biographie*. Kassel - Basel: Bärenreiter, 1988.

[12] J. Cage, "Experimental Music" [1957]. In *Silence. Lectures and Writings*, pp. 7-12. Hanover, NH: Wesleyan University Press, 1961.

[13] J. Cage, "Notes on Compositions II." In *Writer. Previously uncollected pieces*, ed. R. Kostelanetz, pp. 51-62. New York: Limelight Editions, 1993.

[14] D. Rosenboom (ed.), *Biofeedback and the Arts: Results of Early Experiments*. Vancouver: Aesthetic Research Center of Canada, 1976.

[15] A. Schoon, and F. Dombois, "Sonification in Music." *15th International Conference on Auditory Display, Copenhagen, May 18-22, 2009*, Copenhagen 2009. www.ICAD.org (accessed Jan. 6, 2010).

[16] D. Minciacchi, "Translation from neurobiological data to music parameters." In *The Neurosciences and Music*, ed. G. Avanzini, Annals of the New York Academy of Sciences 999, pp. 282-301. New York: New York Academy of Sciences, 2003.

[17] J. Cage, "Notes on Compositions IV." In *Writer. Previously uncollected pieces*, ed. R. Kostelanetz, pp. 133-142. New York: Limelight Editions, 1993.

[18] J. Cage, "Ryoanji: Solos for Oboe, Flute, Contrabass, Voice, Trombone with Percussion or Orchestral Obbligato (1983–85)." *PAJ: A Journal of Performance and Art*, vol. 31, no. 3, pp. 57-64, Sept. 2009.

[19] C. Thierolf, "Plötzliche Bilder. Die Ryoanji-Zeichnungen von John Cage." In *Hanne Darboven / John Cage. Staatsgalerie moderner Kunst*, ed. Bayrische Staatsgemäldesammlungen München, Kunstwerke 4, pp. 42-76. Ostfildern: Gerd Hatje, 1997.

[20] J. Cage, *Musicage. Cage muses on words, art, music*. Ed. J. Retallack. Hanover, NH: Wesleyan University Press, 1996.

[21] J. Cage, *Ryoanji for Flute with percussion or orchestral obbligato and ad libitum with other pieces of the same title*. Score. New York: Henmar Press, 1984.

[22] H. Vögeli and F. Morach, *Waldspitzpanorama*. Zug, Schweiz: Zuger Kantonalbank [promotional print], no year.

[23] A. Lucier and W. Zimmermann, "[Conversation]." In Zimmermann, *Insel Musik*, pp. 347-350. Köln: Beginner Press, 1981. Originally published Zimmermann, *Desert Plants*, Vancouver: A.R.C. (Aesthetic Research Centre), 1976.

[24] A. Lucier, "Origins of a Form. Acoustical Exploration, Science, and Incessancy." *Leonardo Music Journal*, vol. 8, pp. 5-44, 2005.

[25] H. D. Thoreau, *Walden* [1854]. Ed. J. L. Shanley, The Writings of Henry D. Thoreau. Princeton, NJ: Princeton University Press, 1971.

[26] H. D. Thoreau, *Journal. Volume 4: 1851-52*. Ed. L. N. Neufeldt and N. C. Simmons, The Writings of Henry D. Thoreau. Princeton, NJ: Princeton University Press, 1992.

[27] H. D. Thoreau, *Journal. Volume 8: 1854*. Ed. S. H. Petrulionis, The Writings of Henry D. Thoreau. Princeton, NJ: Princeton University Press, 2002.

[28] H. D. Thoreau, *Journal. Volume 5: 1852-53*. Ed. P. F. O'Connell, The Writings of Henry D. Thoreau. Princeton, NJ: Princeton University Press, 1997.

[29] Kramer, Gregory, B. Walker, T. Bonebright, P. Cook, J. Flowers, N. Miner, and J. Neuhoff, *Sonification Report: Status of the Field and Research Agenda. Prepared for the National Science Foundation by members of the International Community for Auditory Display*: International Community for Auditory Display, 1997. http://www.icad.org/websiteV2.0/References/nsf.html (accessed Aug 31, 2008).

[30] Novalis, *Schriften*. Vol. 1: Das Dichterische Werk. Ed. P. Kluckhohn and R. Samuel. Stuttgart: Kohlhammer, 3rd ed. 1977.

[31] E. F. F. Chladni, *Entdeckungen über die Theorie des Klanges*. Leipzig: Weidmanns Erben und Reich, 1787.

[32] Novalis, *Das Allgemeine Brouillon. Materialien zur Enzyklopädistik 1798/99*. Ed. H.-J. Mähl. Hamburg: Meiner, 1993.

[33] H. I. Khan, *The Mysticism of Sound and Music*. Boston: Shambhala, 1996.

[34] A. Polli, "Atmospheric/Weather Works: Artistic Sonification of Meteorological Data." In *Ylem. Artists Using Science & Technology*, vol. 24, no. 8, pp. 9-13, July/Aug. 2004. www.ylem.org (accessed Jan 16, 2010).

[35] C. Hayward, "Listening to the Earth Sing." In *Auditory Display. Sonification, Audification, and Auditory Interfaces*, ed. G. Kramer, Sante Fe Institute Studies in the Sciences of Complexity. Proceedings 18, pp. 369-404. Reading, MA: Addison-Wesley, 1994.