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FROM HELMHOLTZ'S *SENSATIONS OF TONE* TO RUSSOLO'S *ART OF NOISE*[2]

Abstract: In his groundbreaking treatise *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, originally published in 1863, the German physicist and physiologist Hermann von Helmholtz explores the intersections within the domain of art, science and technology. He formulates a proto-psychoacoustical theory of hearing that he proves with the help of the polyphonic sirens and other measuring devices he developed. The new way of hearing proclaimed by Helmholtz significantly promoted the rise of early electronic music in the first two decades of the 20th century and more particularly Russolo's concept of noise and the futuristic (electro)mechanical musical instruments resulting from this.

Key words: physical acoustics, physiological acoustics, measuring devices, electromechanical music, Helmholtz, Russolo.

Introduction

From its day of publication *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (1863), a major work in the scientific oeuvre of the German physicist and physiologist Hermann (von) Helmholtz, strongly captured the attention of many people, not only of all kinds of representatives

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from the domain of science, but also those from the domain of music. It actually does this until our very day. Why? In his founding study of musical acoustics of which a translation has been published entitled *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (1954)[3] – often abbreviated to *On the Sensations of Tone* – he gives an amazing as well as extensive answer to quite an intriguing question: how can we provide the theory of music with scientific foundations? How can we relate these two different kinds of knowledge production? This question has never been resolved in the domains of arts and sciences since the chemist and novelist C. P. Snow delivered his famous Rede Lecture entitled *The Two Cultures and the Scientific Revolution* (1959) in which he traced a lack of mutual understanding between the two professional groups: 'the literary intellectuals' and the natural scientists. It is still catching on to this day.

Helmholtz's standard *On the Sensations of Tone* immediately had a huge impact on the different domains of knowledge production. The historian of science Erwin N. Hiebert and the psychologist Elfrieda F. Hiebert were the first scholars to explore this: how did the authoritative study elicit responses on the part of 'music critics, historians of music, composers, and performers, as well as instrument builders and scientists at home and abroad'?[4] How did it affect the different domains of knowledge production: the artistic, the scientific and the technological one? In their paper, the two Hieberts successively consider the world of scholarly reviews, 'the world of practice' and 'the world of musical instruments'. They show that the most noteworthy and influential critics who went deeply into Helmholtz's treatise, are the musicologist and theorist Hugo Riemann, the psycho-acoustician and philosopher Carl Strumpf, and above all Moritz Hauptmann. This composer and musical theorist conceded that Helmholtz appeared to be an exemplary physiologist, but he called into question the significance of his contributions to the art of music. The composers mentioned by the Hieberts having read the treatise *On the Sensations of Tone*, are Nikolaj Rimsky-Korzakov, George Ives – father and teacher of the more famous Charles, Arnold Schönberg and Paul Hindemith. In this context they examine the work of another composer a little more closely: Leos Janácek. And finally they deal with the engineer Theodor Steinway – inventor of the piano of the same name – who had not just read

[3] The version of Helmholtz' founding study of acoustics used in this context is a model translation: 'The Second English Edition, Translated, thoroughly Revised and Corrected, rendered conformal to the Fourth (and last) German Edition of 1877, with numerous additional Notes and a new additional Appendix bringing information down to 1885, and especially adapted to the use of Music Students by Alexander J. Ellis'. Furthermore, this edition is supplied 'With a new Introduction (1954) by Henry Margenau'.

[4] Elfrieda and Erwin Hiebert, 'Musical Thought and Practice: Links to Helmholtz's *Tonempfindungen*', in: Lorenz Krüger (ed.), Berlin, Universalgenie Helmholtz, 1994, 298.

Helmholtz's book on musical acoustics, but had even had the opportunity to consult him.

Despite their well-documented survey on how the founding study *On the Sensations of Tone* had affected the domain of science, technology, and music the two Hieberts paid no attention to an important subset of the artistic field: early electronic music. Therefore their review lacks the names of a number of important composers, musical theorists and instrument designers after 1900: Thaddeus Cahill, Luigi Russolo, Edgard Varèse and many others.[5] Apparently they don't realise that the development of early electronic music is founded to a great extent on the close connection with 19th century sciences and early technologies, as demonstrated by Helmholtz in his discourse on musical acoustics.

The German historian of science Matthias Rieger has worked up the Hiebert & Hiebert paper in his study *Helmholtz Musicus* (2006). Supplementary to the duo, he also mentions Varèse's engagement with Helmholtz and he refers for instance to the presence of special musical artefacts such as sirens in Varèse's compositions *Amériques* (1918-21) and *Ionisation* (1929-31).[6] Nevertheless, the origin of early electronic music and its relation to Helmholtz's treatise is not revealed by Rieger either. Just as the Hiebert duo does, he misses in his study the crucial comprehension that the emergence of early electronic music marks a radical break in its development from the 19th to the 20th century music. This break is closely connected to Helmholtz's attempts to found the theory of music on a scientific basis.

In order to shed light on how the discourse *On the Sensations of Tone* affected the rise of early electronic music we shall take three steps. First we shall go into Helmholtz's enquiry as an attempt to explore the domain of art, science and technology. Secondly we shall define early electronic music and outline its initial development in relation to Helmholtz's explorations. And finally we shall answer the question why Russolo, one of the key figures in early electronic music, particularly (electro)mechanical music, succeeded in achieving a musical breakthrough partly as a consequence of reading the volume *On the Sensations of Tone* while his contemporaries and immediate predecessors did not.

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[5] The duo Hiebert & Hiebert nor Rieger mention for instance internationally acclaimed Dutch composers who studied Helmholtz's treatise in order to experiment with electronic music: Henk Badings, Rudolf Escher, Roderik de Man and others.

[6] Matthias Rieger, *Helmholtz musicus: Die Objektiveirung der Musik im 19. Jahrhundert durch Helmholtz' Lehre von den Tonempfindungen*, Darmstadt, Wissenschaftliche Buchgesellschaft, 2006, 145.

Helmholtz' explorations *On the Sensations of Tone*

As one of the last 'universal geniuses' of the 19th century – and maybe even the last one in the history of science – Helmholtz embodies the scientific development from natural philosophy into its specialised disciplines, such as astronomy, chemistry and physics, and its professional formations.[7] These tendencies started, roughly speaking, around 1800. Also, the ancient alliance between the arts and natural philosophy that had existed since the days of Early Modern Europe, fell slowly apart.[8]

Halfway in the 19th century Helmholtz observes in the 'Introduction' of his study *On the Sensations of Tone* that the 'horizons of physics, philosophy, and art have of late been too widely separated (…)'.[9] Therefore in his book he undertakes an attempt to connect, so to speak, the science of acoustics and the art of music: 'Now whilst the physical side of the theory of hearing has already been frequently attacked, the results obtained for its physiological and psychological sections are few, imperfect, and accidental. Yet it is precisely the physiological part, especially – the theory of the sensations of hearing – to which the theory of music has to look for the foundation of its structure'.[10] In other words, Helmholtz sets out to connect the domains of physical and physiological acoustics on one side and those of aesthetics and musical science on the other. All in all, *On the Sensations of Tone* contains the formulation and elaboration of a research program which finally demonstrates that 'the theory of harmony and disharmony and of chords can be derived completely from notions of physiological acoustics', as Helmholtz announced in a letter to William Thomson, later also known as Lord Kelvin.[11]

The treatise *On the Sensations of Tone* involves an attempt to explore the relations between the arts and sciences. Starting from the scientific way to produce knowledge, Helmholtz offers a new interpretation of the development of musical acoustics from the ancient Greeks down to the early 19th century discussions

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7 The term universal genius may sound a bit exaggerated, but as a matter of fact it is not. On the occasion of the centennial anniversary of Helmholtz's death a series of scholars from quite different disciplines held his scientific achievements up to light again. These reviews were published in the volume: Lorenz Krüger (ed.), *Universalgenie Helmholtz. Rückblick nach 100 Jahren*, Berlin, Akademie Verlag, 1994.

8 Cf. James Hamilton (ed.), *Fields of Influence. Conjunctions of Artists and Scientists 1815-1860*, Birmingham, University of Birmingham Press, 2001; Pamela H. Smith, 'Art, Science, and Visual Culture in Early Modern Europe', *ISIS*, 2006, 97, 83-100.

9 Helmholtz, 1.

10 Ibid., 4.

11 Stephan Vogel, 'Sensation of Tone, Perception of Sound, and Empiricism', in: David Cahan (ed.), *Herman von Helmholtz and the Foundations of Nineteenth-Century Science*, Berkeley/Los Angeles/London, 1993, 267-68.

on the definition of tone. Regarding the notion of tone he distinguishes two approaches. The process of a sound bridging the distance between source and receiver can be described in a mathematical-physical way. This concerns the physical approach of acoustics. However, this is only half of the story. After the ear has perceived the frequency, it is processed in the inner ear and eventually the resulting stimulus affects brain activity and the accompanying sensation: the sensation of the tone. Helmholtz lumps these two approaches together in his discourse *On the Sensations of Tone*. He connects the theory of the sensations of hearing, as belonging to *physiological acoustics*, and the theory of sound, as belonging to *physical acoustics*. His founding study involves explorations of tone and of what its sensation brings about. He connected physics and physiology, as they emerge in the word 'Tonempfindungen', the starting point of psycho-acoustics.

Before Helmholtz started his historic enquiries into sound and its human analysis in the 1850s, the domain of physiological acoustics was mainly a grey area in which inexplicable results had often been ascribed to some kind of psychological explanations.[12] His discourse proclaims the emancipation of physiological acoustics by synthesizing physical and psychological acoustics, an amalgamation creating a new scientific domain. Or to put it less scientifically: physiological acoustics deals with a border area – and what takes place there – between, so to speak, the outside and the inside. One of the important scientific results unfolded in the treatise *On the Sensations of Tone* is the mapping of this area. Helmholtz formulates a series of physiological-physical hypotheses, but in order to be able to prove these presumptions in an experimental way, he also designs the measuring devices which engineers constructed under his orders. To these artefacts belong all kinds of sirens and resonators, and even a simple kind of vowel syntheziser.

The study *On the Sensations of Tone* is strongly instrument based. This distinguishes 19th century science. Natural grounds can be entered with the help of measuring instruments. These artefacts mediate the relationship of human beings – for instance an experimentor – with the world. More precisely, the perception of natural objects is not just guided by means of artefacts, but these objects also constitute new subject matters. This process of technical mediation leads to new questions and eventually to new measuring devices.[13] The instrument-based science of the 19th century became increasingly technical.

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[12] Initially combination tones were interpreted as 'subjective phenomena'. Cf. Helmholtz, 'Ueber Combinationstöne', *Annalen der Physik*, 1856, 497.

[13] Cf. Peter Paul Verbeek, *What Things Do. Philosophical Reflections on Technology, Agency, and Design*, Pennsylvania, The Pennsylvania State University Press, 2005. The process of technical mediation can be interpreted in a post-phenomenological way or an anthropological one, as done by Don Ihde and Bruno Latour respectively.

Helmholtz proved to be a pioneer in producing knowledge in an early technoscientific way by following his physical approach to the physiological process of hearing, and mediating it with sirens and other devices. In his explorations *On the Sensations of Tone,* he reveals a deep insight into how his physiological-physical hypotheses have to be verified.[14] They are proven by applying not only the precise measuring instruments, but rather the human ear *in collaboration with* these siren-based devices. The human ear is also a measuring device. By executing his acoustical experiments with the help of artefacts specifically invented, he literally penetrates into the human ear and is able to analyse it more deeply than anyone had done before. Where this attempt of physio-physical penetration ends, according to Helmholtz's insights into the analysis of the sensations of tone, *psychological acoustics* begins. The domain of research that the German scholar discloses in his publication *On the Sensations of Tone* can be considered as proto-psychoacoustics. Based on his physiological-physical experiments he constitutes a new way of hearing. It is technically mediated by the siren and other measuring devices. Or, conversely, the sensations of tones, evoked by the measuring devices, constitute a new subject matter, i.e. a new way of hearing.

Helmholtz's physiological-acoustical programme, originally laid down in just a handful of scientific papers and later in the study *On the Sensations of Tone*, resulted, as said before, in the formulation of a new theory of hearing, consisting of several separate theories.[15] One of these theories concerns the so-called resonance hypothesis connecting the various physical manifestations of sound with their physiological analysis. The whole theory of hearing is based on this hypothesis. Helmholtz succeeded in proving it with the help of various designed and applied measuring devices, but none of them was actually siren-based. On the one hand, he demonstrated as a physicist - following in the footsteps of the French mathematical physicist Joseph Fourier - that every complex sound can be decomposed into a series of sinusoidal harmonics, or partials. The frequencies of the harmonics (higher partials) are equal to multiples of the frequency of the fundamental (first partial). On the other hand, he presented as a physiologist the hypothesis that the human ear analyses this sound exactly as it can be decom-

[14] Before Helmholtz entered the domain of acoustics, the physiologist in him had studied various aspects of nerves. From his background as a physiologist and physicist he came to his hypothesis, that each tone or specific tone (the physical aspect) is sensed by a separate nerve ending (the physiological aspect). The question then is: how are these two aspects connected?

[15] The most important of these scientific papers are: 'Ueber Combinationstöne', *Annalen der Physik und Chemie*, 1856, 497-540, 'Ueber die physiologische Ursachen der musikalischen Harmonie', originally a lecture delivered in Bonn, 1857, published in: *Vorträge und Reden*, Volume 1, Braunschweig, Friedrich Vieweg und Sohn, 1896, 119-155, and 'Ueber die Klangfarbe der Vocale', *Annalen der Physik und Chemie*, 1859, 280-290.

posed mathematically. The ear functions, so to speak, as a frequency analyzer. Helmholtz considered the cochlea of the human ear metaphorically as a kind of little piano of which the strings resonate with the corresponding partials of the sound perceived. Although this metaphor did not hold up, Helmholtz indicated where to search for the foundations of psycho-acoustics. His new theory of hearing implicated that every sound could be synthesized by a number of sinusoidal components. It was not necessary anymore to construct a complicated elastic body such as a musical instrument in order to produce a complex sound. A number of sine waves would do as well.

Starting from the resonance hypothesis, Helmholtz was able to reform the domain of physiological acoustics in a fundamental way. He demonstrated the existence of combinational tones, he proved the conjecture that tone quality depends on the relative intensities of higher harmonics, and finally he designed a new, double siren in order to prove another major result of his research programme: the so-called beat theory of consonance and dissonance. Next to the resonance hypothesis, this is the second keystone of his new theory of hearing, and the one with which he completed his synthesis of physical and physiological acoustics.

Initially Helmholtz's research programme in his study *On the Sensations of Tone* involves the exploration of the proto-psychoacoustical hypotheses underlying the new way of hearing, but at a later stage also their application to the theory of music. This can be considered an investigation into the relations between the domain of the humanities and that of technoscience, specialized in music and sound. His programme involves an endeavour to connect the boundaries of physical and physiological acoustics on the one side, explored on the basis of experiments, and those of aesthetics and musical science on the other side. Namely, Helmholtz's researches how the artistic and the technoscientific domains are related.

After the execution of his acoustic research program, reported in by far his most important publication in this field, he concludes that he should proceed further into the aesthetics of music, for instance by focussing on the theory of rhythm, forms of composition, and means of musical expression. However, the explanation of 'the wonders of great works of art' would demand a far more psychological approach. Helmholtz ends his standards *On the Sensations of Tone* with this very sentence: 'But, however alluring such an aim may be, I prefer leaving others to carry out such investigations, in which I should feel myself too much of an amateur, while I myself remain on the safe ground of natural philosophy, in which I am at home'.[16]

[16] Helmholtz, 1954, 371.

Early Electronic Music

In the broadest sense Helmholtz's discourse *On the Sensations of Tone* concerns the domain of art, science and technology, but in a more narrow sense it relates to a subset of this area, namely the field of the intersections between the sonic domain and the technoscientific one. Electronic music belongs to this subset as well. It consists of sounds produced by electromechanical or electronic devices.

We can divide the history of electronic music into various technoscientific focal points. The first technoscientific hub has to be situated in the first decades of the 20th century. In particular in this period of early experiments, composers and engineers were guided by the study *On the Sensations of Tone*. They gave interpretations of the scientific definitions and findings and/or the technological devices presented in Helmholtz's treatise. As far as these interpretations concerned measuring devices, they led to (electro)mechanical instruments. The most illustrious of them are the so-called Telharmonium, the futuristic noise intoners or *intonarumori* and other siren-based instruments.

It is almost too good to be true that the history of early electronic music commenced in the first year of the 20th century. Its starting point is often connected with the search for the perfect musical instrument, undertaken by the American lawyer Thaddeus Cahill, an engineering handyman and inventor as well. Noticing the inefficiencies of various instruments, he became interested in the technoscientific domain of music. He pursued the idea a revolutionary musical apparatus that could produce scientifically perfect tones. Furthermore, these tones had to be controlled to a mathematical certainty by mechanical means.[17] In fulfilling this list of demands, Cahill invented an electric musical instrument known as the *Telharmonium* (1900).[18] The inventor himself preferred to call his creation an 'Electric Music Plant'.[19] Basically, it consisted of a number of keyboards connected to a kind of power plant. With the help of dynamos or electric generators it had the capacity to build up complex tones such as musical instru-

[17] Reynold Weidenaar, *Magic Music from the Telharmonium*, Metuchen, N.J., London, The Scarecrow Press, 1995, 14.

[18] Ibid., 18–24; Thom Holmes, *Electronic and Experimental Music. Pioneers in Technology and Composition*, New York/London, Routledge, 2002, 43–44. Before the Telharmonium already some primitive electric musical devices had been invented. The American electrical engineer Elisha Gray introduced the Musical Telegraph (1874) and the English physicist William Duddell presented the Singing Arc (1899). Gray's harmonic telegraph had not been designed or intended as a musical instrument. Nevertheless, Gray's idea of generating music electrically has guided Cahill in his explorations to produce 'electrical music'.

[19] Edwin Hall Pierce, 'A Colossal Experiment in "Just Intonation"', *The Musical Quarterly*, 1924, X:3, 326–327.

ments produced.[20] Therefore it was originally called the Dynamophone. Cahill had figured out that the current from the electric generator could be transmitted by wire to a telephone receiver that could serve as a vibrating body: an attached amplifying horn could produce an audible sine tone. Separate dynamos would be required for the fundamental pitches and additional ones would be needed to produce harmonics. If these dynamos would be synchronized, they could produce complex timbres, completely according to Helmholtz's idea of synthesizing sounds. For a good reason, Cahill called this mechanism a 'synthesizer', but he did not borrow the term from the German scientist.[21] The Electric Music Plant could synthesize all conceivable timbres in any desired pitch. Therefore this invention can be considered as an early precursor of the subsequent synthesizer. As the titles of the various patents on the Telharmonium indicate – they apply for an 'Art of and Apparatus for Generating and Distributing Music Electrically' – the electric musical instrument consists of two divisions: the actual electric music plant, so to speak, the electric harmonium, and its extension by telephonic devices to the outside world. The huge apparatus took up the principle of the already existing telephone concerts.[22] By sending the sounds from the electric power plant through the telephone wires 'telharmonic' music could be enjoyed in public spaces such as hotels, restaurants and theatres, and even in private homes.[23] Not until a later stage was the playing of the electric harmonium also scheduled as a kind of recital in the so-called Telharmonic Hall in New York.[24]

According to Cahill, the invention of his Electric Music Plant possessed the powers of all instruments and the defects of none. It would replace the piano, organ, and violin as the preferred parlour instruments.[25] Unfortunately for him, even the Telharmonium, 'one of the greatest accomplishments of the brain of man', as Lord Kelvin described it, had its limitations.[26] It was too expensive and too huge to transport. The enormous central station made quite some noise and ran into all kinds of technical problems.[27] The music that it produced intruded on other tele-

[20] The Telharmonium made it possible to transform an electric current into a fixed, even infinitely small and mathematical exact number of vibrations.

[21] Weidenaar, 14–15. Cahill had borrowed this idea from his patent on an electric typewriter.

[22] Ibid., 1–4, 16–18.

[23] Ibid., 60–76.

[24] Ibid., 121–228.

[25] Ibid., xiv.

[26] Ibid., 40.

[27] Ibid., 66, 123–124, 141, 186.

phone calls.[28] Furthermore, the timbres created became more and more annoying.[29] Before Cahill had been able to solve these problems, the 'devastating reality' of a completely new medium revealed itself: the wireless that could carry speech and song as well as all kinds of music, albeit produced by traditional instruments.[30]

Cahill's creation of the Telharmonium emanates directly from Helmholtz's treatise *On the Sensations of Tone*. It was based on a measuring device launched in that study: an electromechanical one-note or vowel synthesizer – an apparatus basically made up of an array of tuning forks which were activated by electromagnets and attached to resonance chambers.[31] This measuring device, also known as the tuning fork synthesizer, simultaneously produced simple partial tones with special pitches and intensities in an artificial way.[32] It was able to imitate the sounds of the – German – vowels of the human voice. Helmholtz's tuning fork synthesizer belonged to his most advanced measuring devices, designed when he already had reached an advanced stage in his research on acoustics, to be more precise: on the timbre of complex tones. In his preceding experiments on acoustics, specified in his study *On the Sensations of Tone*, he had mainly applied measuring devices such as sirens and resonators. These tools appealed to the imagination of musicians and technoscientists as well.

Cahill had taken great pains to prove that his invention was able to function properly as a musical instrument. He initiated public demonstrations of his electromechanical devices. In order to prove that it worked as a genuine musical instrument, he mainly applied 'the dignified music of the great masters'.[33] Although Cahill emphasized the musical prospects of his invention, his technoscientific way of knowing hardly gave rise to a new musical way of knowing. He had fallen back on Helmholtz's treatise *On the Sensations of Tone*, it's true, but nevertheless he simply gave too little attention to the consequences of his explo-

28 Ibid., 135–137.

29 Ibid., 186.

30 Ibid., 252, 263.

31 Ibid., 8; Helmholtz, 120–126; Thomas L. Hankins & Robert J. Silverman, *Instruments and the Imagination*, New Jersey, Princeton University Press, 1995, 203–205.

32 Hankins & Silverman, 203.

33 Weidenaar, 60–64; 69–71, 185. Cahill offered the piano and violin teacher Edwin Hall Pierce ample opportunity to play on the pilot model of the Telharmonium. On the 20th of March 1906 he belonged to the musicians who played a number of 19th century compositions in the presence of local and national reporters: the 'Adagio' from Beethoven's *Trio in C Major* for two oboes and English horn, followed by a few of Chopin's Mazurkas, the 'Overture' to Rossini's last opera *William Tell*, Schumann's *Träumerei* and many other compositions. These and other compositions played on the 'the central station instrument' were transferred and sounded 'sweet and clear over the wires'.

rations in the proto-psycho-acoustic domain: a new way of hearing technically mediated by the measuring devices as well as the newly developed instruments applied for synthesizing 'classical' music.

Only a few composers, well-acquainted with Helmholtz's new way of hearing, developed a fascination for the electromechanical musical instruments such as invented by Cahill. Concerning the Telharmonium, the pioneering composer Varèse had become interested in its possibilities. From his years of study he had been involved in the technoscientific way of knowing, arising from Helmholtz's elaborations *On the Sensations of Tone*, the applied measuring devices and their consequences, in order to pursue an innovative musical way of knowing. However, Varèse was quite disappointed when he eventually attended a demonstration of the Telharmonium in New York.[34]

Apart from Varèse, also the German-Italian composer, piano player and theorist Ferruccio Busoni followed the musical way of knowing in order to approach the gap between the artistic and the technoscientific domain. But in his essays and other writings he never referred to Helmholtz's physiological-physical explorations and the technically mediated new way of hearing. Already in 1893 he had written a letter concerning the insufficiency of the means for musical expression.[35] Exploring the insufficiency he muses on paper about 'improvements not yet invented' such as 'new instruments for the future'.[36] In order to acquire richer sonic possibilities, Busoni suggested that music must abandon traditional instruments.[37] In his classical essay entitled *Sketch for a New Aesthetic of Music* (1911) he elaborates on the short reflection in the letter and unfolds his pursuit for a new tonal system. He welcomes the Telharmonium as the new instrument that could be 'set' on every pitch desired; it could even produce an infinite gradation of the octave, simply by moving a lever.[38] Busoni predicts that only 'a long series of experiments, and a continued training of the ear' can make the Telharmonium approachable and usable for art.[39] He points to this musical artefact resulting from the technoscientific way of knowing, but he hardly connects it to his artistic way of knowing.

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34 Ibid., 254; Louise Varèse, *Varèse, A Looking-Glass Diary*, Volume I: 1883–1928, New York, 1972, 50.

35 This letter was found in his posthumous papers.

36 Ferruccio Busoni, *The Essence of Music, and Other Essays*, London, Rockliff, 1957, 38.

37 Robert P. Morgan, '"A Modern Musical Reality": Futurism, Modernism, and "The Art of Noises"', *Modernism/Modernity*, 1994, 1.3, 132.

38 Busoni, 'Sketch of a New Aesthetic of Music', in: *Three Classics in the Aesthetic of Music,* New York, Dover Publications, 1962, 94–95; Weidenaar, 254.

39 Busoni, 1962, 95.

To put this last conclusion in another perspective, after the publication of his *Sketch for a new Aesthetic of Music,* Busoni displayed more than once an ambivalence towards the relations between the artistic and the technoscientific way of knowing. Varèse has confirmed the ambiguous attitude of the musical theorist on several occasions. On the one hand, he approvingly cites for instance this prophecy by Busoni: 'I almost think that in the new great music, machines will be necessary and will be assigned a share in it. Perhaps industry, too, will bring about its share in the artistic ascent'.[40] And he concludes from this: 'How right he was, for it is thanks to industry that composers today compose by means of electronic machines invented for industry's benefit but adopted by composers, with the assistance of engineers for theirs'.[41] Varèse interprets Busoni's prophecy completely in terms of the relations between the artistic and the technoscientific domain. He was able to make at least one step further than Helmholtz, because of the emergence of the technoscientific complexes after 1900. On the other hand, Varèse was astonished that the same man who developed unconventional musical theories and discussed the Telharmonium, composed works so little in accordance with his own ideas.[42] It came as a surprise to him that Busoni's musical tastes and his own music were so orthodox.[43] This showed once more during his American tours of 1910 and '11. Busoni only played the traditional repertory and he apparently made no efforts to see or listen to the Telharmonium in New York.[44]

Back in Europe, Busoni chose to stay in the merely classical regions of the artistic domain. Only one more time he referred publicly to the Telharmonium and in this way to a musical artefact of the technoscientific domain. In the autumn of 1912 he gave a written response to an unsigned Futurist Music Manifesto published in a Parisian newspaper.[45] Concerning the aesthetic laws of Futurism, pursuing 'nothing more than the division of an octave into fifty intervals', he observes that he stood 'on this side long ago, if only as a theorist'.[46] In his *Sketch for a New Aesthetic of Music* he had claimed something similar: a division of the octave into thirty-six intervals. With a view on the production of futuristic music, the manifesto predicts the rise of fami-

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40 Varèse, 50.

41 Varèse, 50.

42 Fernand Ouellette, *A Biography of Edgard Varèse*, New York, The Orion Press (Grossman Publishers), 1968, 24–25.

43 Weidenaar, 254.

44 Ibid.

45 Busoni, 1957, 28–29. *The Futurist Music Manifesto* was published in *La Liberté*, the 1st of March 1912, Busoni's response in the periodical *Pan*, September 1912.

46 Ibid., 28.

lies of instruments 'whose unsuspected perfection will make the perfect reproduction of compositions possible'.[47] According to Busoni such a universal instrument already had been made in America: an electric dynamic organ.[48] Although it is far from any elaboration, the manifesto slightly indicates how any suggestion in the artistic domain may result in new musical artefacts from the technoscientific domain.

Futurist's music

The manifesto entitled 'The Musical Futurism' is attributed to F.T. Marinetti, the founding father of Italian Futurism, and/or Francesco Balilla Pratella, the musical theorist of the movement. But it remains unclear who really wrote it. Therefore it is ambiguous as to which of the two pamphleteers suggested that new musical artefacts were needed to produce the futurist sounds. The import of the programme in the Parisian paper fits in with the manifestos on futurist music which Pratella published, but the world-shattering tone rather refers to Marinetti. The initiator and leader of the Futurist movement pursued a very tight editorial regime concerning the manifestos not written by himself.[49] More than once Pratella complained that some affirmations of a polemic and other ones of a theoretical nature referring to a rapport between music and the machine, were neither written nor even thought of by him.[50] Marinetti hadded these inventions at his own insistence. An example of such a more futuristically tuned addition is the final conclusion of Pratella's *Technical Manifesto of Futurist Music* (1911):

> *Contain in music all the new attitudes of nature that are always tamed by man in different ways by virtue of his incessant scientific discoveries. Give musical animation to crowds, great industrial shipyards, trains, transatlantic steamers, battleships, automobiles, and airplanes. Add the domination of a machine and the victorious reign of Electricity to the great central motive of a musical poem.*[51]

In this appeal the artistic and the technoscientific domain are connected, albeit in a more passionate than conceptual style. The rest the manifestos published by Pra-

47 Ibid.

48 Ibid.

49 Rodney J. Payton, 'The Music of Futurism: Concerts and Polemics', *The Music Quarterly*, 1976, 62, 32.

50 Ibid. Contrary to his second manifesto Pratella's first manifesto does not hold any reference to music and machine.

51 Michael Kirby, *Futurist Performance*, New York, PAJ Publications, 1986, 165.

tella deal with theoretical terms for futurist music.[52] His approach of the new music has to be positioned entirely in the artistic realm, under the condition that Marinetti emphasized the relation between that domain and the technoscientific one. After establishing the theoretical premises of futurist music, Pratella had to put them into practice. In the winter of 1913 he directed the *Hymn to Life, Futurist Music for Orchestra*, the first composition according to his futuristic axioms, twice in Rome.[53] Although the audience reacted very frantically, in retrospect Pratella's composition was not as revolutionary as expected.[54] It simply sounded too conservative to reflect the futurist aesthetic principles adequately. Besides, this impression of deficiency was reinforced by the typical 19th century ensemble with its bourgeois instruments which performed the *Futurist Music for Orchestra*.

After attending Pratella's composition in which his musical principles of Futurism were brought to sounds, another member of Marinetti's movement wrote a letter to the composer almost immediately after the second performance. This Futurist was the painter Luigi Russolo. Encouraged by his observation that the performed music did not sound fantastically futuristic, he emphasized in his missive that Pratella's musical principles were not founded precisely enough. Furthermore,

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[52] Ibid., 160–165; Balilla Pratella, 'Manifesto of Futurist Musicians 1910', in Umbro Apollonio (ed.), *Futurist Manifestos*, Boston, MFA Publications, 2001, 31-37; Esther Schmitz-Gundlach, *Musikästhetische Konzepte des italienischen Futurismus,* München, M-press, 2007, 31-49. In his *Manifest for Futurist Musicians* (published on the 11th of October 1910 in Milan) Pratella urges the destruction of the past and the prejudice for 'well-made' music from 19th century European as well as Italian origin. His *Technical Manifesto of Futurist Music* (the 11th of March 1911, Milan) is an elaboration of the first one. In his second manifesto he makes a plea for a drastic differentiation of the following musical parameters: melody, harmony, rhythm, instrumentation and musical form. In particular he goes into the possibilities of enharmonic music by using smaller subdivisions of tones than the usual chromatic ones. His third manifesto called *The Destruction of Quadrature* (the 18th of July 1912) presents a theory of the poly-rhythmic including phenomena of speech. In this manifesto he also introduces the term bourgeois music that he already intended to destroy in his first manifesto. Theoretically, he succeeds in this intention in his third manifesto. Sometimes a fourth manifesto on futurist music is attributed to Pratella: *Against the Mighty* (the 15th of May, 1913). In this pamphlet he scoffs at the mighty in nature and bourgeois music. Then he presents the anti-mighty as the alternative way: the programme of the futurist music.

[53] Payton, 33–35. The first two performances of Pratella's *Hymn to Life, Futurist Music for Orchestra* took place in Theatre Costanzi in Rome on the 21st of February and the 9th of March 1913. Together with the three manifesto's the composition was already published in an issue entitled *Musica Futurista di Ballila Pratella* (1912).

[54] Payton (1976), 33–35. During the second performance of Pratella's *Hymn to Life, Futurist Music for Orchestra* a pandemonium broke loose: 'Some people in the audience threw upon the orchestra 'an uninterrupted shower of garbage, of fruit, of chestnut cake; others shouted themselves hoarse crying every kind of thing'.

he adhered to the opinion that his colleague had not taken up the consequences of his musical principles with regard to the set of instruments to be used.

Only two days after the Pratella concert, Russolo published his considerations under the title *The Art of Noises*.[55] This 'futurist manifesto', as said, in the form of a letter to 'Dear Ballila Pratella, Great Futurist Composer', establishes the principles of futurist music and their consequences for musical practice. Based on his experiences with the Pratella concert, he tries to lay down this observation in his manifesto:

> *We Futurists have all deeply loved and enjoyed the harmonies of the great masters. Beethoven and Wagner have stirred our nerves and hearts for many years. Now we have had enough of them, and we delight much more in combining in our thoughts the noises of trams, of automobile engines, of carriages and brawling crowds, than in hearing again the 'Eroica' or the 'Pastoral'.*[56]

According to Russolo all these machines have created 'such a variety and contention of noises that pure sound in its slightness and monotony no longer provokes emotion'.[57] Musical sound is simply too limited in its variety of timbres. Therefore he states: 'We must break out of this limited circle of sounds and conquer the infinite variety of noise-sounds'.[58] Russolo's conclusion that the demarcation between musical and other sounds was too tight, goes back to the treatise *On the Sensations of Tone*, as the Futurist had indicated in an elaboration of his manifesto, entitled 'Physical Principles and Practical Possibilities'.[59] In the very first chapter of his treatise, Helmholtz describes the principal difference between various sounds experienced by our ears as that between musical tones and noises: 'The sensation of a musical tone is due to a rapid periodic motion of a sonorous body; the sensation of a noise to non-periodic motions'.[60] The tones of all musical instruments are examples of the first kind; the soughing, howling, and whistling of the wind, the splashing of water, the rolling and rumbling of carriages are examples of the second kind. After reading this simple definition of a musical tone, Russolo concluded that the musical sounds of the 19th century bourgeois orchestras were too limited in their variety of timbres. They had to be enlarged to the infinite va-

[55] The original title of this 'futurist manifesto' is: *L'Arte dei Rumori*. It was published as a separate issue by the Direzione del Movimento futurista (Direction of the Futurist Movement) on the 11th of March 1913.

[56] Luigi Russolo, *The Art of Noises*, New York, Pendragon Press, 1986, 25.

[57] Ibid., 24.

[58] Ibid., 25.

[59] Ibid, 37-40.

[60] Helmholtz, 7–8.

riety of other sounds, in particular the noise-sounds produced by machines and other artefacts of modern life. To put it very simply: Russolo extended the notion of music by opening the windows to let the outside noises in.

In order to work out his musical programme, Russolo pursued a new starting point of music and he ended up on the treatise *On the Sensations of Tone*. He developed a musical theory for Futurism based on Helmholtz's scientific definitions of musical tones and other sounds. His precursor Busoni and his futurist colleague Pratella, did not just stick to old concepts of music - although given a kind of adjusted twist - but also to the old musical instruments. Russolo, on the other hand, related his revolutionary findings in the artistic domain to the technoscientific one in order to make this revolutionary concept more than just an idea on paper: he intended to make it audible. In his manifesto he distinguishes six families of fundamental noises which he was able to realize mechanically with a series of musical devices called 'intonarumori' or noise-intoners.[61] These devices invented and constructed with the help of the painter Ugo Piatti, consisted of odd-shaped boxes, a noise producing a toothed-wheel siren based on a mechanism inside them, and outside a handle on top, a lever at the back, and huge metal speakers at the front.[62] They had been given quite meaningful names, almost onomatopoeic ones: the Burster ('scoppiatore'), the Crackler ('crepitate'), the Hummer ('ronzatore'), the Rubber ('stropicciatore') and so on… An electric control rather than a crank handle activated some of the noise-intoners.[63] Therefore these musical devices do definitively belong to the set of electro-mechanical instruments.

About one year after the proclamation of *The Art of Noises*, only a few months before the beginning of the First World War, Russolo himself directed the first Grand Futurist Concert in Milan.[64] An orchestra made up of eighteen noise instruments and just as many formally dressed musicians performed three 'networks of noises' called *Awakening of a City*, *Dining on the Hotel Terrace* and *The Meeting of Automobiles and Airplanes*.[65] Russolo did not consider himself as a composer. His musical works were not genuine compositions or impressionistic reproductions

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61 Russolo, 1986, 28. Actually the *intonarumori* did not make very much noise. Regarding this the designation noise-intoner or its French equivalent *bruiteur* is at least a little bit exaggerated.

62 Both Futurists did not dispose of an expanded technical ingeniousness. Therefore the noise-intoners which they built, may be considered the product of animated dilettantism.

63 Cf. www.l-m-c.org.uk/texts/russolo.html, 020-02-2009.

64 This 'Gran Concerto Futurista d'Intornarumori' took place on the 21st of April 1914 at the Teatro dal Verme in Milan.

65 Russolo, 18, 33. Some papers and reports mention a fourth 'network of noises' being performed, entitled *Skirmish at the Oasis*, but this piece was never completed.

of modern life, but rather demonstrations, 'moving hypotheses of noises'.[66] The concert resulted in a pandemonium of gurgling, crackling, exploding and hissing sounds. A performance that ended in a deafening uproar.[67] Would the sirens of the rushing police have been sounding by then?

Russolo has given an account on his development as a music theorist and an inventor of new instruments in a series of short papers which are collected, together with the original manifesto-letter, in a book also entitled *The Art of Noises*.[68] These elaborations on the consequences of his manifesto show how closely his artistic and technoscientific way of knowing are entangled. The results he achieved in the one domain led to actions in the other domain, and vice versa. He invented a number of musical artefacts based on the *interaction* between the musical and the technoscientific field. From a scientific base, Russolo extended the notion of music into that of noise or sound. After that he materialized these artistic-theoretical attainments in the form of technoscientific artefacts. Constructing and practicing the noise intoners, he discovered the microtonal potentialities of his devices. This demanded a new musical notation and Russolo suggested the enharmonic one.[69] With this technical mediated invention of the enharmonic notation, he achieved another result in the artistic domain which gave rise to inventions in the technoscientific domain. Russolo invented an Enharmonic Bow, partly derived from a Roarer and a Crackler: a metal rod with periodic indentations of grooves with which the strings of a violin or cello could be bowed.[70] Eventually he invented an enharmonic piano, but he never completed it: a kind of mechanized prepared piano in which the sound is created by rosined belts rubbing against metal springs.[71] Artistic-theoretical considerations and results had encouraged him to go back to the technoscientific domain.

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66 Ibid., 18.

67 Ibid., 33–34; Ingo Bartsch, *Russolo: Die Geräuschkunst 1913–1931*, Bochum, Museum Bochum, 1985, 49.

68 The original title of this book is: *L'Arte dei Rumori*. Contrary to the manifesto the subtitle 'manifesto futurista' has been omitted. It was published by the Edizione Futuriste di 'Poesia' in Milan 1916. In this enquiry several translations of the Italian original have been used: *The Art of Noises*; Translated from the Italian; With an Introduction by Barclay Brown (1986), *Die Kunst der Geräusche*; Aus dem Italienischen von Owig DasGupta; Herausgegeben und mit einem Nachwort versehen von Johannes Ullmaier (2000), and *L'Art des Bruits*; Textes établis et présentés par Giovanni Lista; Traductions de l'Italien par Nina Sparta (1975, 2001).

69 Russolo, 1986, 67–70.

70 Ibid., 1986, 7, 16; Bartsch, 42.

71 Russolo, 1986, 17; Russolo, 2001, 120–125. A one octave prototype of this instrument is the only thing left from Russolo's inventions. The rest disappeared. Most of the instruments appear to have been destroyed during the Second World War.

Russolo's experiences with the performances of the noise orchestra instigated him to create a few more interventions. He decided to add conventional instruments to his noise orchestra. Then he also had to touch upon the question of the possibility of adding the noise instruments to the conventional orchestra.[72] According to Russolo this step was a 'logical and natural' consequence of his artistic-theoretical way of knowing.[73] It led to the formation of what Pratella coined the 'mixed orchestra'. However, his experiences with the performances of the *intonarumori* also incited him to unify the noise intoners in a new electromechanical instrument: a so-called *Rumorarmonio* or Noise Harmonium.[74] The *Russolophone*, as it was also called, generated the timbres of all of his earlier instruments. A whole noise orchestra combined in one single instrument. It could produce all the sounds distinguished in the manifesto on *The Art of Noise*: from natural sounds to noises.[75] The concert practices of the noise-intoners, so to speak, had brought Russolo back to the technoscientific domain. The Noise Harmonium can be considered the final result of his movements back and forth between the artistic and the technoscientific domain.

Quite a few composers became enthusiastic about Russolo's latest musical invention.[76] Among them: Varèse, the visionary composer who had rejected the principles of the Futurist Movement before.[77] As a pursuer of new sounds he repeatedly emphasized the need for new instruments.[78] He became so enthusiastic

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72 Russolo, 1986, 6.

73 Ibid.

74 Ibid., 7–9, 15–16; Bartsch, 1985, 40. Russolo built four of these Noise Harmoniums which he called *Psofarmoni*. In the initial copies the original levers of the noise intoners were replaced by keys.

75 Russolo, 1986, 16. Russolo used the Noise Harmonium to accompany avant-garde silent movies in Studio 28 in Paris during the late 1920s.

76 Bartsch, 1985, 46; Fred K. Prieberg, *Musica Ex Machina*, Über das Verhältnis von Musik und Technik, Berlin/Frankfurt/Wien, 1960, 44–45; Franco Tagliapietra & Anna Gasparotto, *Luigi Russolo. Vita e opere di un futurista*, Ginevra/Milano, Skira, 2006, 117. These composers include: Franco Casavola, Arthur Honegger and Maurice Ravel.

77 Cf. Varèse, 106: 'Why is it, Italian Futurists, that you slavishly imitate only what is superficial and most boring in the trepidation of our daily lives!' According to Varèse the Futurists reproduce noise too much for its own sake, rather than applying it to expand the horizons of musical expression. Cf. See also: Olivia Mattis, 'Varèse's Multimedia Conception of. Déserts', *The Musical Quarterly*, 1992, 76 (4), 583, footnote 80.

78 Cf. Ouellette, 46–47: In an interview published in the New York Telegraph on the 11th of March 1916 Varèse gave one of his famous statements: 'Our musical alphabet must be enriched. We also need new instruments very badly. The Futurists (Marinetti and his noise artists) have made a serious mistake in this respect. Instruments, after all, must only be a temporary means of expression. Musicians should take up this question in deep earnest with the help of machin-

about the Noise Harmonium that he even planned to put it into mass production. Varèse predicted that Russolo's invention with its potentialities and its user-friendliness would acquire a place in the orchestra quite soon.[79] That thought was a little too optimistic. The same holds for the suggestion of mass production. It never happened. And in spite of his enthusiasm Varèse did not even apply the *Rumorarmonio* to his compositions. Nevertheless, the fact remains that Russolo's Noise Harmonium was the last major achievement of early electronic music.

Putting Russolo's activities in the artistic and technoscientific domain in a somehow wider perspective in the end, we may draw the following conclusions from the early days of electronic music. In the beginning of his explorations as an innovator and inventor Russolo simply expanded the realm of music. He indicated a shift from *music as tones* to *music as sound*.[80] Contrary to Cahill who pursued *music as tones* with the aim to demonstrate that his electronic device can truly function as a musical instrument, Russolo engaged his noise intoners and other inventions in order to produce *music as sound*. A lot of succeeding composers devoted to electronic music actually did the same as Cahill. Within the framework of an expanded musical realm, as initiated by Russolo, they considered the new instruments simply as possible extensions of the traditional set of acoustic instruments, belonging to symphony orchestras or other musical ensembles.[81] Contemporary as it may sound, the work of many of these composers must be considered as *music as tones*, just like that of their classical and romantic predecessors.[82] Composers following in Russolo's footsteps, worked the other way around. They were not interested in the bourgeois approach of *music as tones*, but they pursued *music as sound*. These composers called for a new concept of music followed by the pursuit of new musical instruments that would meet that theoretical starting point. After Russolo,

ery specialists. I have always felt the need of new mediums of expression in my own work. I refuse to submit myself only to sounds that have already been heard. What I am looking for are new technical means which can lend themselves to every expression of thought.'

79 Prieberg, 44–45. Cf. http://luigi.russolo.free.fr/varese.html, 03-02-2009.

80 Timothy D. Taylor, *Strange Sounds*, Music, Technology & Culture, New York / London, 2001, p. 3. Taylor introduces the notion of *music as sound* as well as that of *music as bits*, but he does not really develop them. In this thesis the two notions in question are extended with a third one: *music as tones*.

81 Among the composers who worked with vacuum tube-based electronic instruments such as the Theremin and Ondes Martenot were Percy Grainger, Bohuslav Martinu and Olivier Messiaen, Darius Milhaud, Arthur Honegger and Tristain Murail. Paul Hindemith wrote a number of compositions for the Trautonium. Furthermore, a lot of rock groups made use of a Theremin, such as the Beach Boys in 'Good Vibrations', Captain Beefheart & His Magic Band in 'Electricity' and Led Zeppelin in 'Whole Lotta Love'. Radiohead's Jonny Greenwood often applies the Ondes Martenot.

82 The same holds for the synthesizers and other instruments based on integrated circuits.

the most far-reaching composer adhering to this approach was Varèse. In the late 1930s he even proclaimed 'Music as an Art-Science', an early attempt to relate the sonic and the technoscientific way of knowing more directly. In this context he looked for an entire new medium of expression: 'a sound *producing* machine (not a sound-*reproducing* one)' with potentialities which an orchestra with its man-powered instruments cannot perform.[83] Russolo's explorations in the domain of sound, science and technology created the necessary preconditions for electronic music, not only its early manifestations, but also its latter ones.

Џон Хејманс

ОД ХЕЛМХОЛЦОВЕ *ОСЕТЉИВОСТИ ТОНА* ДО РУСОЛОВЕ *УМЕТНОСТИ БУКЕ*

САЖЕТАК

Осврнућем на електронску музику, посебно у првој фази развоја електромеханичких инструмената, покушали смо да поставимо следеће питање: како је читање Хелмхолцове (Hermann von Helmholtz) расправе *О осетљивости тона* утицало на музичаре и градитеље инструмената? То се догодило на неколико начина.

Кахил (Cahill) је започео своје активности у домену технонауке: пропагирао је различите верзије својих електромеханичких инструмената заснованих на апарату за мерење који је настао као резултат Хелмхолцових истраживања у поменутој расправи. У почецима ових истраживања уметничка и технонаучна област готово да нису доведени у везу. Хелмхолцови музички апарати су тестирани према утабаним стазама у домену уметности. Они никада нису постали технички посредници у новој музичкој концепцији.

Са друге стране, Бузони (Busoni) и, у мањој мери, Варез (Varèse) започели су теоријска размишљања о уметности: изложили су своје радикалне визије о новој музици, али из различитих разлога њихова гледишта нису била подржана од стране музичких проналазача. Ти концепти нису продрли у домен технонауке, те су са обе стране пропали покушаји повезивања уметничког и технонаучног начина знања.

Међутим, Русоло, који се бавио музиком, успео је да повеже ове две области. Футуристи су, пошавши од научних дефиниција у Хелмхолцовој студији, проширили буржоаску музику 19. века на оно што је Хелмхолц почетком 20. века назвао буком. Овај револуционарни корак је водио до следећег: Русоло је учинио свој концепт буке чујним. То је утицало на развој технички посредованих музичких аксиома на које је указано у манифесту *Уметност буке*. Следећи ове теоријске елаборације о музици и већ створивши одређене технонаучне артефакте, Русоло је изумео неколико нових музичких инструмената. Најзначајнији међу њима је хармонијум буке, настао из синтезе знања о теорији музике и технонауци, као и завршетку почетног периода електронске музике.

[83] Varèse, 'Music as an Art-Science', in: Elliot Schwartz & Barney Childs with Jim Fox, *Contemporary Composers on Contemporary Music*, New York, 1998, p. 200.

С обзиром на наведено закључак је јасан: у покушају да доведе у везу уметничку и технонаучну област, Русоло се испоставио као наследник Хелмхолца у области музике, јер је он, као физичар и физиолог, учинио исто што и Русоло.

Кључне речи: физичка акустика, физиолошка акустика, уређаји за мерење, електромеханичка музика, Хелмхолц, Русоло.