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Sounds of Science – Schall im Labor (1800–1930)

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Introductory Remarks

The following collection of papers documents the workshop "Sounds of Science – Schall im Labor, 1800 to 1930," carried out at the Max Planck Institute for the History of Science, Berlin October 5 to 7, 2006. It was organized within the context of the project "Experimentalization of Life: Configurations between Science, Art, and Technology" situated in Department III of the Institute. While the larger project has discussed topics such as "Experimental Cultures," the "Materiality of Time Relations in Life Sciences, Art, and Technology (1830-1930)," "Science and the City," "Relations between the Living and the Lifeless," and the "Shape of Experiment" in workshops and conferences, this workshop asked about the role sound plays in the configurations among science, technology and the arts, focusing on the years between 1800 and 1930. The chronological point of departure was the appearance of a registration technique: in 1802 Ernst Florens Friedrich Chladni published his book on acoustics where he extensively described the *Klangfiguren* – his visualizations of the movements of a vibrating, sounding body. This time span was also characterized by the systematization of research into hearing, which Hermann von Helmholtz greatly promoted through his book *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, which first appeared in 1863. Helmholtz's resonance theory of hearing described in this book was not replaced by a new explanation for the process of hearing until the end of the 1920s, which gives another temporal delineation for the workshop. Furthermore, between 1800 and 1930 a wealth of technical innovation in the realm of acoustical media occurred: in addition to a series of visualization techniques for sound, the phonograph and gramophone, microphone and loudspeaker, telephone and radio were invented. As well, the music of European tonal composition underwent a radical change during this time that led to a collapse of the tonal system and provoked the demand for music composed of sounds and noises, rather than tones.

Conference participants were invited to discuss the role of sounds in the laboratory from different angles, in three parts. The "Materiality of Sound" was oriented towards research into material cultures and cultural techniques in experimentation. "Registration, Transmission, Transformation" put questions of medial historiography into the foreground, while "Experimental Aesthetics" thematized aesthetic implications. But these three points of departure were not understood as exclusive; and no strict separation between an aesthetic and an epistemological approach or a historical approach focusing on media or on sciences was intended. On the contrary, the intersection of such questions was brought forward and the circular arguments into which the configurations among sciences, technology and the arts are constantly forced were traced in the discussion.

In the first part, "Materiality of Sound," it was discussed how sound as it is being heard became an object of scientific research. Developments in nineteenth-century physiology contributed to an increasingly material conception of sound and thereby greatly furthered laboratory research on sound. With this, an interdisciplinary form of research came into being that involved physics and instrument making, musicology, phonetics or ethnology. The functioning of the ear was recreated in laboratories: sounds were synthesized and new sound sources invented; music and its instruments were investigated to lay bare the implicit knowledge that was assumed to be hidden in compositions, theories of harmony or in musical instruments. This research was accompanied by a constant adjustment of the material culture of experiment into what could be heard as the materiality of sound. This includes the experiments and the standardization of instruments and measuring devices; it concerns the exchanges between scientists and musicians, laboratories and workshops for musical and scientific instruments; it also comprises the invention of new sounds in music and the advent of electricity in the lab. All these developments caused sound to be heard in new ways.

The second part, "Registration, Transmission, Transformation," aimed to connect this history of sound in the laboratory with the appearance of new media technologies. Sound is fleeting; it only subsists as a mediated object, and historical research on sound always relies on some mediation. This medial condition of sound generates specific problems and questions that were addressed in this part of the workshop. The "méthode graphique" or the "phonautograph" allowed repeated access to recordings of fleeting sound events. Ensembles of sirens, resonators, the harmonium and tuning forks enabled the arbitrary production of well-defined sound. With the use of the phonograph and gramophone, sound became independent of its original context. Thus, ephemeral sound was molded into a scientific object by the interplay of experimental science and media technologies. The media technologies of recording, transmission and transformation also made a new phenomenality of sound audible. Within sound there were tones and clangs, signals and noise, information and distortion. In many cases, the discussion therefore set the bridge to the aesthetic issues that were focused on in the third part of the workshop.

Under the heading of "Experimental Aesthetics," the third part of this workshop considered the interrelation between science and music, researchers and composers, laboratories and concert halls. By transforming hearing into a scientific object, it could become a "problem" as Gaston Bachelard would term it. This affected the status of music. Nineteenth-century physiology appropriated the history of music as a kind of prehistory of the physiological theory of hearing. Experimenters believed that the Western tonal system reflected the ear's ability to analyze sound, that music theory and composition were both grounded in calculable processes of hearing, and that the history of music mirrored the physical laws of hearing. Some fundamental notions of musical aesthetics – consonance and dissonance, scales, triads and modes – apparently could be confirmed experimentally, and yet the postulated systematic connection between physiology and musical aesthetics did not hold. The experiments did not reveal a natural order in the system of music, but found instead an arbitrary ordering. Nineteenth-century research on hearing could not provide a physiological foundation for musical aesthetics. Musical aesthetics did, however, heavily inform research on hearing. This can be seen in the choice of sound sources that were brought into action in the laboratory and can be followed in the experimental set-ups that produced beats and combination tones, and finally in the wordings and choices of hypotheses that were tested experimentally.

The poster for this workshop shows the shadow of a human figure in front of a blackboard. In the middle of this blackboard we see the schematic drawing of a tape recorder. The person who made the drawing was the radio journalist, researcher and composer Pierre Schaeffer. The variety of domains he worked in seems to be symptomatic of the fact that it is not so simple to designate a starting point from which to talk about sound and hearing. This was mirrored in the fact that historians of science, media and culture, philologists, musicologists and philosophers gathered to discuss the history of sound in the laboratory. These introductory remarks offer me the

opportunity to thank them for their willingness to participate in the interdisciplinary endeavor. Also, I would like to thank those who helped to make this workshop possible: my colleagues from the project on the "Experimentalization of Life", especially Sven Dierig and Henning Schmidgen, for their support in developing the concept of this workshop, Britta Lange, Katrin Solhdju and Wolfgang Lefèvre for chairing sessions, and Hans-Jörg Rheinberger for participating as a commentator; Antje Radeck, Leona Geisler, Mirjam Lewin, Philipp Messner, and Frederik Schulze for organizational support, and Angelika Irmscher for providing the layout of this preprint. Also, I would like to thank the Museum of Musical Instruments SIMPK and its director, Conny Restle, for hosting a concert, which gave a special note to the enterprise: I am deeply grateful to Florian Hoelscher and Marco Stroppa for the chance to hear "Miniature Estrose" in the framework of this workshop.

Julia Kursell

„Erzklang“ oder „missing fundamental“: Kulturgeschichte als Signalanalyse

Bernhard Siegert

Wenn die Worte, ferne Spende,
sagen –
nicht bedeuten durch bezeichnen –
wenn sie zeigend tragen
an den Ort
uralter Eignis,
– Sterbliche eignend dem Brauch –
wohin Geläut der Stille ruft,
wo Früh-Gedachtes der Be-Stimmung
sich fügsam klar entgegenstuft.

Martin Heidegger, „Sprache“[1]

1.

Am Tag vor Weihnachten des Jahres 1814 schrieb Goethe ein Gedicht, dem er den Titel „Dreistigkeit“ gab.

> Worauf kommt es überall an,
> Daß der Mensch gesundet?
> Jeder höret gern den Schall an
> Der zum Ton sich rundet.
>
> Alles weg! was deinen Lauf stört!
> Nur kein düster Streben!
> Eh er singt und eh er aufhört,
> Muß der Dichter leben.
>
> Und so mag des Lebens Erzklang
> Durch die Seele dröhnen!
> Fühlt der Dichter sich das Herz bang
> Wird sich selbst versöhnen.[2]

1814 wird Napoleon nach Blüchers Sieg bei La Rothière zur Abdankung gezwungen. Angeblich soll es noch im Dezember Kämpfe gegeben haben. Ob nun mit „Erzklang“ das Donnern der Kanonen oder das Donnern der Glocken gemeint ist, macht akustisch zwar einen Unterschied, gehört aber in Goethes Klangwelt in dasselbe napoleonische Paradigma, wie ein Brief an Charlotte von Stein von 1812 aus Carlsbad beweist, den Goethe folgendermaßen beschließt:

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[1] In: Martin Heidegger, *Gesamtausgabe*, 1. Abt., Bd. 13: *Aus der Erfahrung des Denkens, 1910-1976*, Frankfurt/M.: Klostermann, 1983, S. 229.

[2] Johann Wolfgang von Goethe, „Dreistigkeit“, in: ders., *Werke*, hg. von Erich Trunz, Hamburger Ausgabe, Bd. 2, 14. Aufl. München: Beck, 1989, S. 16.

Was werden Sie aber sagen, wenn es nicht in meiner Macht steht anders zu datiren als
Carlsbad
den 15. August
als am Napoleonsfeste
beym stärksten Glockengeläute
und Kannonendonner treu gewidmet
1812. Goethe.[3]

Glocken und Kanonen vermischen sich nicht nur in der Wahrnehmung von Napoleonsfesten, sondern auch im Realen. Womit die Artillerie der Revolutionsheere und die Armeen des Artilleriegenerals Bonaparte schossen, waren alles ehemalige Glocken. Seit 1793 waren aus einem großen Teil der Kirchenglocken Frankreichs Kanonen gegossen worden. Man schätzt, daß 100.000 Glocken, die von 60.000 Glockentürmen stammten, während der Revolutionszeit eingeschmolzen worden sind.[4] Auch in den deutschen Staaten war die Metamorphose zu Kanonen ein den Turmglocken oftmals vorherbestimmtes Schicksal. Die Konfiskation der Glocken in Kriegszeiten gehört in Europa zu einer fest verankerten Tradition. Der Chef der Artillerie hatte im neuzeitlichen Europa Anspruch auf die Glocken einer eroberten Stadt (das ist das sog. Glockenrecht).[5]

Die Frage, mit der das Gedicht beginnt, unterstellt Lyrik unmittelbar dem Diskurs der Medizin: „Worauf kommt es überall an, / daß der Mensch gesundet?“ Die Antwort negiert in ihrem arroganten Phonozentrismus das medientechnische Faktum, daß alle Lyrik mit den Buchstaben des Alphabets anfängt, um stattdessen mit dem Bild des Sängers einen Ursprung in einer akustischen Operation zu unterstellen: „Jeder höret gern den Schall an / Der zum Ton sich rundet.“

Dichtung ist ein System, das seine Grenze zur Umwelt erst generieren muß durch Filterung eines Rauschens – durch Herausfilterung all dessen am Schall, das sich nicht zum Ton runden will.[6] Akustisch gesprochen: alle nichtperiodischen Anteile im Klangspektrum des Außen. Mit anderen Worten: Geräusch, Rauschen. Idiophone aus Erz, Holz oder Stein produzieren mehr Rauschen als jedes andere Musikinstrument, weil ihre Harmonischen keine ganzzahligen Vielfachen des Grundtons sind und untereinander chaotische, weil nicht-rationale Verhältnisse besitzen. Filterung eines Rauschens stellt die Elemente der Poesie allererst her, anstatt sie als Alphabet vorzufinden.

Aber nicht genug, daß das Gedicht von dieser Operation der Rundung spricht; es führt in einer selbstreferentiellen Operation an sich selbst das vor, wovon es spricht. Die Hälfte der vokalischen Reime endet mit einem Spondeus, der dort den Trochäus ersetzt (Spondeus: zwei Hebungen – –, Trochäus: Hebung-Senkung – ‿). Während der Spondeus (– –) die unmenschlichen Erzklänge si-

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3 Johann Wolfgang von Goethe, *Goethes Werke*, hg. im Auftrage der Großherzogin Sophie von Sachsen, Weimar: Böhlau,1905, IV. Abt.: *Goethes Briefe*, Bd. 23, S. 73.

4 Vgl. Alain Corbin, *Die Sprache der Glocken: Ländliche Gefühlskultur und symbolische Ordnung im Frankreich des 19. Jahrhunderts*, übers. von Holger Fliessbach, Frankfurt/M.: Fischer, 1995, S. 44.

5 Vgl. Corbin, *Die Sprache der Glocken*, S. 28.

6 Vgl. Friedrich A. Kittler, „Ein Subjekt der Dichtung“, in: ders., Gerhard Buhr und Horst Turk (Hg.), *Das Subjekt der Dichtung: Festschrift für Gerhard Kaiser*, Würzburg: Königshausen & Neumann, 1990, S. 399-410.

muliert („bang!“), rundet der Trochäus (–‿) den Klang. Der Wechsel von A-Reimen zu B-Reimen vollzieht die Versöhnung, die Aufhebung des bloßen Schalls zum verinnerlichten Ton.

Daher ist Dichtung zugleich ein System, das – weil Dichtung dem medizinischen Diskurs untersteht – auch das Subjekt generieren muß. Was ein Subjekt zum Subjekt macht, und was den Dichter insbesondere zum Dichter macht, ist die Herausfilterung alles Chaotischen aus „des Lebens Erzklang“. Anders gesagt: die Glocke ist das Andere von Kultur, insofern Kultur mit dem Medium des Alphabets gleichgesetzt wird, und das Andere des Subjekts. Dieses Subjekt ist nach Goethe strikt als Rückkopplungseffekt von Dichtung konstruiert. Im Sich-Selbstvernehmen, in dem der Autor in hegelischer Selbstvermittlung zugleich Subjekt und Objekt der Dichtung ist, konstituiert sich das System des Kultur-Anthropologischen als Negation des Nichtvermittelbaren, des Nichtschreibbaren und des Nichtberechenbaren.

2.

Die Kultur- und Wissenschaftsgeschichte des Glockenklangs liefert ein Beispiel dafür, wie man Kulturgeschichte als Signalanalyse schreiben kann. Was für eine Art von Geschichte kann der Klang der Glocke haben? Ich meine, es gibt zwei Arten: Entweder man interpretiert den Glockenklang als Zeichen, dann schreibt man eine kultursemiotisch fundierte Geschichte von Gefühlskulturen (das ist von Alain Corbin gemacht worden[7]). Oder man faßt den Glockenklang als Signal im physikalischen Sinne auf und hält sich an die signalanalytische Beschaffenheit dieses Dings. Voraussetzung dafür ist allerdings wiederum medienhistorisch die technische Möglichkeit zur Aufzeichnung und Prozessierung von akustischen Ereignissen, die sich der notenschriftlichen Aufzeichnung schlichtweg kategorisch verweigern. Meine Methode, Kulturgeschichte in Signalanalyse zu fundieren, steht also unter einem Medienapriori, das ich nicht zu verheimlichen gedenke, im Gegenteil.

In der Berliner Medienwissenschaft wird gern die Unversöhnbarkeit von Medienarchäologie und Kultursemiotik betont: „Medienarchäologie akzentuiert [...] Signal- statt Zeichenverarbeitung, gerade im Unterschied zur Kultursemiotik.“[8] Aber eine nachrichtentheoretisch fundierte Medienwissenschaft, die historischen Sinnbildungsprozessen fernsteht, ist keine Medienarchäologie, sondern nichts anderes als eben Nachrichtentheorie. Medienarchäologie ist nur dann Archäologie, wenn sie nicht Signal- gegen Zeichenverarbeitung setzt, sondern einen Begriff kultureller Zeichen aus der Signalanalyse gewinnt. Also nicht Signal- *statt* Zeichenanalyse, sondern Zeichenanalyse *als* Signalanalyse.

Die abendländische Harmonik wurde über Jahrhunderte durch das am Vokalalphabet orientierte System der Notenschrift stabilisiert. Die Parameter, die durch Komponisten und Musiker als Variable zu handhaben und daher manipulierbar waren, waren Tonhöhe (also Frequenz), Tondauer (Zeit) und Lautstärke (Amplitude), wobei letztere auch nicht im technischen Code der Notenschrift, sondern nur alltagssprachlich notierbar war. Was das Notenschriftsystem nicht anschreiben kann, ist die Klangfarbe, ist also das, was metonymisch auf die Instrumente in ihrer dinghaften Materialität verweist. Klangfarbe sorgt dafür, daß wir eine Flöte als Flöte, eine Geige

7 Corbin, *Die Sprache der Glocken,* S. 44.
8 Wolfgang Ernst, „Von der Mediengeschichte zur Zeitkritik“, *Archiv für Mediengeschichte* 6 (2006), S. 23-32, hier S. 25.

als Geige und ein Klarinette als Klarinette identifizieren. Wobei angemerkt werden muß, daß der größte Teil der Klangfarbeninformation im Einschwingvorgang des Signals und in seinen Formanten enthalten ist.

Was ist der Glockenklang kultursemiotisch? Ursprünglich haben Glocken in ihrer sakralen Funktion Signalcharakter: Ihr Läuten ist ein Zeichen, das ein Zeichen ankündigt. Die Sprache der Glocken – das wußte niemand besser als der ehemalige Mesmerbub Martin Heidegger, dessen Lieblingskinderspielplatz der Glockenturm in Meßkirch war[9] – ist ein Rufen, das sein Gerufenes näher bringt, das es versammelt. „Das versammelnde Rufen ist das Läuten."[10] Oder mit den Worten von Pink Floyd auf *Dark Side of the Moon*:

> Far away, across the field
> The tolling of the iron bell
> Calls the faithful to their knees
> To hear the softly spoken magic spell.[11]

> Auch wenn die Kirche – in [...] Predigt und Liturgie [...] – wesentlich aufs Wort des [Großen] Anderen baut, das sie verkünden oder verstärken soll, so trägt doch keine Menschenstimme dieses Wort [...] laut und weit genug. Über die Kirchenschiffe hinaus, selbst wenn sie eigens als Schallverstärker konstruiert worden sind, reichen nur Geräusche. Deshalb paktieren Diskursmächte mit einer Übermacht, Schöpfungen mit einem Tohuwabohu – auf die Gefahr hin, daß es sie immer auch überwältigen und übertönen kann.[12]

Der im Glockenturm aufgewachsene Heidegger hat in seinen späten Jahren die Sprache der Glokken als Wesen der Sprache überhaupt zu bestimmen versucht. „Die Sprache spricht als das Geläut der Stille."[13] In nachrichtentechnischer Terminologie: Die Sprache spricht als Signal-Rausch-Abstand, wenn wir Stille sinnesphysiologisch, thermodynamisch und nachrichtentechnisch korrekt mit Grundrauschen übersetzen und Geläut kulturtechnisch korrekt mit Signal. Das Wesen der Sprache liegt nicht in ihrem Kommunikations-, sondern in ihrem Signalcharakter. Daß es die Turmglocke ist und nur sie allein, die dieses Wesen der Sprache immer schon ausgesprochen hat, ist Kern meiner heutigen Rede. Von diesem Ruf sind die säkularen Funktionen der Glocke als Alarmsignal abgeleitet. Wenn nicht gerade ER zum „magic spell" ruft, läuten Glocken, wenn der Feind naht oder wenn's brennt.

Wie Corbin gezeigt hat, war das Recht auf ein bißchen Lärm, das Recht, die Ohren zu betäuben, Gegenstand zahlreicher lokaler Auseinandersetzungen im postrevolutionären Frankreich des 19. Jahrhunderts. Das neue revolutionäre Regime in Paris dokumentierte die souveräne Macht der Nation gegenüber den lokalen Würdenträgern und Autoritäten durch das Verbot, die Kirchenglocken zu läuten bzw. die Glocken abnehmen zu lassen (bis 1830). Nationale Souveränität ist Signalherrschaft.

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9 Martin Heidegger, „Das Geheimnis des Glockenturms", in: ders., *Gesamtausgabe*, 1. Abt., Bd. 13, S. 113-116.

10 Heidegger, „Die Sprache", in: *Unterwegs zur Sprache*, in: ders., *Gesamtausgabe*, 1. Abt., Bd. 12, Frankfurt/M.: Klostermann, 1985, S. 7-30, hier S. 27.

11 Pink Floyd, „TIME", auf: *Dark Side of the Moon*, EMI Italiana, 1973.

12 Kittler, „Ein Subjekt der Dichtung" (Typoskript), S. 11.

13 Heidegger, „Die Sprache", S. 27.

In Dorothy Sayers Roman *Die Neun Schneider* werden die neun gewaltigen Glocken einer ländlichen Pfarrkirche zu Mördern. Auf dem Friedhof von Fenchurch St. Paul wird kurz nach dem Weihnachtsabend ein Toter mit furchtbar verzerrten Gesichtszügen gefunden. Lord Peter Wimsey grübelt bis zum Schluß des Romans über die rätselhafte Todesursache, bis er durch Zufall in der Glockenstube des 40 m hohen Turms von einem Feiertagsläuten überrascht wird. Der Erzklang der Glocken hat das Opfer, das sich dort oben ans Gebälk gefesselt befand, erst zum Wahnsinn getrieben und dann gemordet.[14] Was aus der Ferne eine „Gefühlskultur" gewesen sein mag, in der Glockengeläut eine kommunitarische Identität hergestellt hat,[15] ist von nahem erfahren einfach etwas Grauenhaftes. Was aus der Ferne das Gefühl des Erhabenen induziert, ist in der Nähe bloß das unerträglich Schreckliche.

Glocken markieren die Grenze zum Wahnsinn, die Grenze zwischen Nüchternheit und Rausch, die Grenze zum Ausnahmezustand (Krieg, Katastrophen), die Grenze zwischen Gott und Mensch, die Grenze zwischen Leben und Tod. Das wäre sozusagen das kultursemiotische Resümee, das ich nun mit einem signalanalytischen Argument verbinden will. Glocken – so meine These – repräsentieren und signalisieren im Symbolischen den Ausnahmezustand, weil sie im akustisch Realen der Ausnahmezustand sind. Aus diesem Grund sind Glocken Medien, weil sie das Vermittelte, die Botschaft der Eucharistie oder des Ausnahmezustandes, unter Bedingungen setzen, die sie selbst schaffen und sind.[16]

Der Glockenklang bildet im Herzen des ländlichen, kleinstädtischen Europas ein Netz verteilter lokaler Zentren, in dem sich eine Kultur organisiert durch den Pakt mit dem Chaos, das im Register der christlichen Mythen und Symbole den Teufel und im Register der Codes und der Instrumente ein prinzipiell Unschreibbares bezeichnet.

3.

Nach diesem sehr gerafften kultursemiotischen Abriß der Glocke nun eine ebenso geraffte Skizzierung der Rolle der Glocke in der Geschichte der wissenschaftlichen Akustik. Lehrbücher über die Physik musikalischer Instrumente beginnen noch heute mit d'Alemberts Wellengleichung. Das mit gutem Grund. Denn mit der Wellengleichung hat die mathematische Akustik ihr erstes Fundament erhalten, das dann in der Folge von Leonhard Euler und Fourier auch gleich wieder dekonstruiert werden sollte. Zwar sollte man die Geschichte der experimentellen Akustik nicht anfangen lassen, ohne Simon Stevin, Marin Mersenne und Robert Hooke zu erwähnen, die auf experimentellem Wege an einem neuzeitlichen mathematischen Begriff der Tonhöhe und des Intervalls arbeiteten, der auf absoluten Schwingungszahlen basierte. Mersenne verlängerte die Saite des Monochord auf rekordverdächtige 12 Ellen, so daß er ihre Schwingungen zwar nicht mehr hören, dafür aber mit dem Auge verfolgen konnte, und extrapolierte dann aus der Verkürzung dieser Saiten die Schwingungszahlen hörbarer Töne. Robert Hooke verfolgte auf Londons Straßen Fliegen und andere brummende und summende Insekten, deren Summton er solange nachsummte, bis er zu Hause am Klavier seine Höhe

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[14] Vgl. Dorothy Sayers, *The Nine Tailors*, London: Victor Gollancz, 1934.
[15] Vgl. Corbin, *Die Sprache der Glocken*, S. 15.
[16] Lorenz Engell und Joseph Vogl, Editorial, *Archiv für Mediengeschichte* 1 (2001), S. 6.

ermitteln konnte, um so akustisch die Frequenz zu berechnen, mit der die Flügelchen der Insekten schwirrten.

Aber erst d'Alemberts Wellengleichung machte es möglich, eine geschlossene mathematische Formel für sämtliche Schwingungsereignisse eines bestimmten Typs anzugeben. Die Wellengleichung in ihrer klassischen Form erfaßt periodische Schallereignisse, die von eindimensionalen schwingenden Körpern hervorgerufen werden, also von Saiten oder von Luftsäulen in Blasinstrumenten. Wesentlich problematischer wird es, wenn man von Punktstrahlern, die ja hauptsächlich für den Klang eines handelsüblichen westeuropäischen Orchesters verantwortlich sind, zu Flächenstrahlern übergeht, also zu schwingenden Membranen oder Idiophonen wie sie die Instrumentierung wesentlich nichteuropäischer Kulturen ausmachen. Chladnis Klangfiguren, die die Knotenlinien von schwingenden Kupferplatten sichtbar machen, vertraten explizit die um 1800 gegebene Unmöglichkeit, den Sound von zweidimensionalen Schwingungskörpern analytisch darzustellen. Man hätte dazu sämtliche willkürliche (d.h. auch stückweise unstetige) Funktionen analytisch darstellen müssen, die als Lösungen die zweidimensionale d'Alembertsche Wellengleichung erfüllen. Ganz zu schweigen von dreidimensionalen Idiophonen, wie es Glocken sind, die zugleich zwei Arten von Schwingungen ausführen: Querbiegungsschwingungen und Längsbiegungsschwingungen.[17]

Hinzu kommt, daß bei großen Glocken (und nur von Turmglocken rede ich hier, nicht von Glockenspielglocken (carillons) oder Meßdienerbimmeln) die Frequenzen der Obertöne (der sogenannten „Harmonischen") nicht mehr ganze Vielfache der Grundfrequenz sind (wie bei Saiten- oder Blasinstrumenten). Weil ihre Harmonischen ihren Namen Lügen strafen, nennt man den Klang der Glocke, dessen Schwingungsform nicht mehr rein periodisch ist, auch anharmonisch.

Mit Jean Baptiste Joseph Fouriers Abhandlung über die Ausbreitung der Wärme, die er 1807 im Institut de France den versammelten Mathematikern Frankreichs vortrug, wurde – traditionell wissenschaftsgeschichtlich gesprochen – der mathematischen Akustik ihr bis heute existenzbegründendes mathematisches Analysewerkzeug geschenkt. Ohne Fourieranalyse hätten wir keine Ahnung vom realen Grund oder Abgrund unserer Klangkultur. Mittels Fourieranalyse läßt sich die materiale Welt, insofern sie aus elastischen Körper-, Schall-, Wärme- und Ätherschwingungen besteht, analysieren und in unendlichen Summen von trigonometrischen Funktionen anschreiben. Eine gerade Linie war seitdem keine Strecke zwischen zwei Punkten mehr, sondern ein unendlich feines Vibrieren des Raums. Die Dinge verloren ihre Konturen oder besser gesagt, ihre Konturen verschwammen in den Hitzewellen, die den Raum erfüllen, weil sie aus Hitzewellen sind. Die Materie Fouriers *wabert.*

Fouriers Resultat ist also: Jede periodische Funktion, die einen wohl-definierten Graphen besitzt, kann durch eine Gleichung vom Typ

$$f(t) = \frac{a_0}{2} + \sum_{k=1}^{\infty} (a_k \cos k\omega t + b_k \sin k\omega t)$$

dargestellt werden.

[17] Vgl. Andreas Weissenbäck und Josef Pfundner, *Tönendes Erz: Die abendländische Glocke als Toninstrument und die historischen Glocken in Österreich*, Graz und Köln: Böhlau, 1961, S. 7f.

Fouriers Lösung war fünfzig Jahre zuvor bereits von Daniel Bernoulli als allgemeinstmögliche Lösung der d'Alembertschen Wellengleichung vorgeschlagen worden. Bernoullis Ansatz basierte auf der Annahme, daß „alle tönenden Körper potentiell eine Unendlichkeit von Tönen einschließen und eine Unendlichkeit von entsprechenden Weisen, ihre regelmäßigen Schwingungen auszuführen.“[18] Welcher Art diese Schwingungen auch sein mochten, fügte Euler hinzu, kontinuierliche oder diskontinuierliche. Tatsächlich ist der von Bernoulli vorgeschlagene und von Fourier durchgeführte Prozeß mathematisch derselbe wie bei der Analyse von musikalischen Tönen in ihre Grund- und Obertöne. In der Musik konvergiert eine solche Reihe sehr schnell zu Klangfarbenidentitäten.

Dennoch: Bis ins zwanzigste Jahrhundert repräsentierte die Glocke für die mathematische Akustik das Jenseits des Berechenbaren, weil ihre Form fast unlösbare partielle komplexe Differentialgleichungen dritter Ordnung verlangt.[19] Wenn man also zwar weiß, daß der Klang einer jeden Glocke in einem Fourierintegral enthalten ist, man aber nicht über die Möglichkeiten verfügt, die für diesen Klang maßgeblichen Harmonischen zu ermitteln, dann ist die Fourieranalyse der Glocke zuvörderst eine Sache der Experimentalwissenschaft. Aber eben diese experimentelle Akustik erlebte, als sie sich in der Person Lord Rayleighs 1890 zum ersten Mal mit experimenteller Fourieranalyse des Erzklangs annahm, ihr blaues Wunder. Lord Rayleigh mußte feststellen, daß es unmöglich war, mittels Stimmgabelresonatoren den für die Tonhöhe von Glocken zuständigen idiophonischen Grundton festzustellen. Die Glocke markiert den Ausnahmezustand der physikalischen Akustik.

4.

Der Tonaufbau der Glocke besteht aus zwei verschiedenen Komponenten: erstens den physikalisch realen Schwingungen der Summtöne und der höheren Obertöne, die mit Meßapparaturen nachweisbar sind, und zweitens dem Schlagton. Der Schlagton ist der vorherrschende Schlagklangeindruck, den eine Glocke beim Läuten hervorruft. Nach ihm wird die Stellung der Glocke bezüglich der Tonhöhe in einem Geläute bestimmt. Eben dieser Schlagton galt bis in die sechziger Jahre des 20. Jahrhundert als ein unerklärliches Phantom. Während man nämlich die Summtöne und die Obertöne der Glocke einzeln nach der Helmholtzschen Methode durch Resonatoren nachweisen und oszillographisch aufzeichnen kann, läßt sich ausgerechnet der am stärksten hervortretende Ton, der die Tonhöhe der Glocke bestimmt, nicht unter den meßbaren Frequenzen (auch nicht unter den Schwebetönen) finden. „Bei den Turmglocken tritt die [...] merkwürdige Erscheinung auf, daß der Ton, nach welchem eine Glocke benannt wird, der

[18] Daniel Bernoulli, „Réflexions et éclaircissemens sur les nouvelles vibrations des cordes exposées dans les mémoires de l'Académie de 1747 & 1748“, *Histoire de l'Académie Royale des Sciences et Belles Lettres de Berlin* 9 (1753), S. 151. – Meine Übersetzung.

[19] Vgl. Neville H. Fletcher und Thomas D. Rossing, *The Physics of Musical Instruments*, New York u.a.: Springer, 1991 (erschienen 1994). – Die von Kittler in diesem Zusammenhang erwähnte „General Bell Formula“ hat mit diesem Problem der mathematischen Akustik gar nichts zu tun, sondern bezieht sich erstens auf eine Glockengießerformel und zweitens auf „carillons“, also auf die kleinen Glocken eines Glockenspiels, die einen völlig anderen – viel einfacheren – Fall darstellen. Vgl. André Lehr, „A General Bell Formula“, *Acustica* 2/1 (1952), S. 35-38.

sogenannte *Schlagton*, im allgemeinen nicht im Spektrum der Glocke vorkommt.“[20] Lord Rayleigh mußte sich daher mit einer empirischen Regel begnügen.[21] Demnach sollte der Schlagton eine Oktave unter der Tonhöhe der fünften Eigenfrequenz liegen. Und noch 1961 mußte das campanologische Hauptwerk für die Glocken Österreichs bekennen, „daß der Schlagton noch nicht mit technischen Hilfsmitteln, sondern lediglich mit dem Ohr in seiner Tonhöhe fixiert werden konnte.“[22]

1930 gelang es Franklin G. Tyzzer zum ersten Mal, die Glockenteiltöne mithilfe von Knotenkreisen und Meridiankreisen zu klassifizieren. In den dreißiger Jahren standen schließlich die technischen Medien zur Verfügung, um mit anderen Mitteln als mit Stimmgabelresonatoren das Geheimnis der Glocke zu lüften.

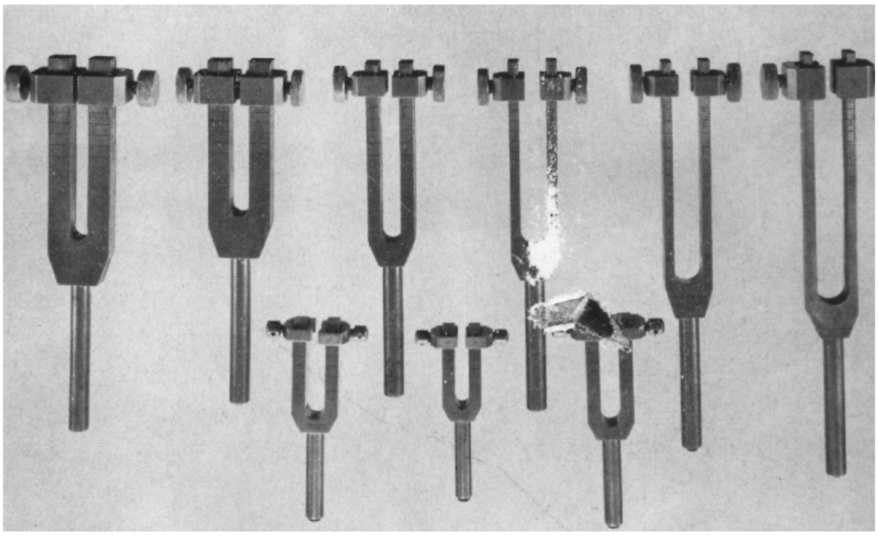

Abb. 1: Verstellbare Stimmgabeln von Prof. Edelmann, München, für die Tonhöhen von Fis bis a/3.

[20] Jan F. Schouten, „Die Tonhöhenempfindung“, *Philips' Technische Rundschau* 5/10 (1940), S. 294-302, hier S. 301.
[21] Lord Rayleigh, „On Bells“, *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 5. Ser., 29/176 (Januar 1890), S. 1-17.
[22] Weissenbäck und Pfundner, *Tönendes Erz*, S. 13.

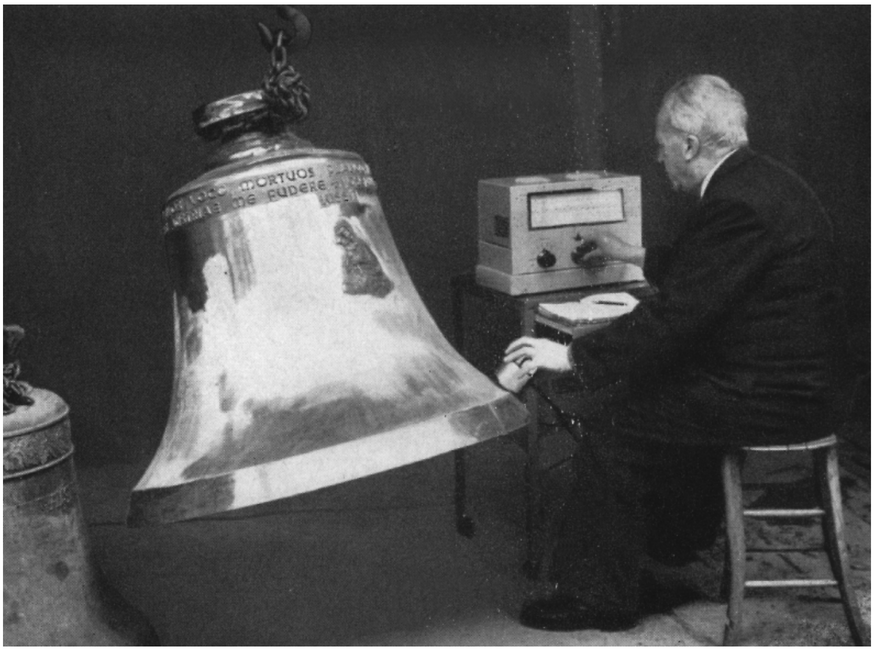

Abb. 2: Experimentelle Fourieranalyse, ca. 1960. Feststellung der Teiltöne mit elektrischem Abstimmgerät.

Schon Ferdinand Braun in Straßburg hatte die Kathodenstrahlröhre als Medium zur Visualisierung von Schwingungskurven verwendet, das heißt als Oszilloskop. 1921 hatte Carl Stumpf in seinem Berliner Psychologischen Institut zum Telephon gegriffen, um seine Formanttheorie der Konsonanten zu bestätigen.[23] Daraufhin griff der Präsident des Telegraphentechnischen Reichsamtes Karl Willy Wagner seinerseits zur Formanttheorie: In die Telephonleitung eingeschaltete Drosselketten brachten anstandslos die von Stumpf vorhergesagten Formantregionen zu Gehör, die es Wagner erlaubten, auf ihrer Grundlage das für eine hinreichende Verständlichkeit am Telephon notwendige Frequenzband neu zu bestimmen.[24] Mikrophone, Oszilloskope und vor allem Drosselketten, die es ermöglichen, auf elektromagnetischem Wege experimentelle Fourieranalysen durchzuführen, gehörten von nun an zur Standardausrüstung der experimentellen Akustik,[25] die auch in den Labors von Telephonkonzernen wie der AEG, Siemens oder AT&T betrieben wurde. Daher ist es auch kein Zufall, daß Jan Schouten seine Residuums-Theorie der Schlagtonhöhe 1940 in *Philips' Technischer Rundschau* publizierte.

Erst seit es gelungen ist, einen Algorithmus für Fouriertransformationen zu implementieren, ist man in der Lage, das Klangsignal von Turmglocken einer objektiven Tonhöhenanalyse zu unterziehen. Man gewinnt seit 1982 die Teiltonfrequenzen und -amplituden aus einem digitalen mittels Fast Fourier Transform berechneten Fourierspektrum.[26]

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23 Vgl. Carl Stumpf, „Über die Tonlage der Konsonanten und die für das Sprachverständnis entscheidende Gegend des Tonreiches“, *Sitzungsberichte der Preußischen Akademie der Wissenschaften* 1921, 2. Halbbd., S. 639.

24 Vgl. Karl Willy Wagner, „Der Frequenzbereich von Sprache und Musik“, *Elektrotechnische Zeitschrift* 45 (1924), S. 451-456.

25 Vgl. E. Meyer und J. Klaes, *Über den Schlagton von Glocken*, Berlin 1933.

1940 publizierte, wie gesagt, der Niederländer Jan Schouten seine Residuums-Theorie. Schouten war glühender Anhänger der bereits von Helmholtz vertretenen Idee, daß die Basilarmembran in der Cochlea „imstande ist, [...] Fourier-Analyse durchzuführen."[27] Nun macht aber das Ohr bei der Wahrnehmung eines aus verschiedenen Harmonischen bestehenden Klanges keinen Gebrauch von seiner Fähigkeit zur Analyse, sondern vermittelt nur den Eindruck eines Klanges von bestimmter Tonhöhe und Klangfarbe. Die Herstellung einer Klangfarbenidentität dominiert die Fähigkeit, den Ton in seine Obertöne aufzulösen. Nun weiß man, seitdem es technisch möglich ist, einen Klang in seine Obertöne zu zerlegen, daß wir einem Ton immer die Tonhöhe des Grundtones zuschreiben, auch wenn der Grundton im Klangspektrum gar nicht vorhanden ist.[28] Vor allem das Telephon, das den ganzen Frequenzbereich unterhalb von 300 Hz abschneidet, lehrte die Akustiker die Einsicht in dieses Phänomen. In dem weggefilterten Frequenzbereich liegen zwar die Grundtöne der männlichen Stimme und zum Teil auch die der weiblichen, dennoch erfährt die Stimmhöhe des Sprechers keine Änderung.

Bei Schoutens Versuchen mit periodischen Impulsen, die eine Obertonreihe ohne Grundschwingung darstellten, blieb dennoch ein „starker, scharfer Klang" mit der Frequenz der real fehlenden Grundschwingung wahrnehmbar. Auch wenn weitere niedrige Harmonische aus dem Spektrum entfernt werden, bleibt dieser Ton hörbar. Er verschwindet erst, „wenn die höchsten Harmonien aus dem Klang herausgeholt werden."[29] Diese Klangkomponente nannte Schouten das „Residuum". Es siedelt in einem Bereich, in dem die Harmonischen so dicht beeinander liegen, daß das Auflösungsvermögen des Ohres nicht ausreicht, um sie voneinander zu unterscheiden. Konkret verursachen Frequenzen von 2000, 2200, 2400 Hz usw. zusammen in der Basilarmembran eine Klangempfindung von 200 Hz. Die Frage ist nur, warum sie eine Komponente von so niedriger Tonhöhe bilden. Schoutens Erklärung: nicht die Frequenz der Harmonischen und nicht ihr Abstand voneinander tragen zur Bildung des imaginären Grundtons bei, sondern die Frequenz ihrer Hüllkurve.

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[26] Vgl. Ernst Terhardt und Manfred Seewann, „Auditive und objektive Bestimmung der Schlagtonhöhe von historischen Kirchenglocken", *Acustica* 54/3 (1984), S. 129-144, hier: S. 131.
[27] Schouten, „Die Tonhöhenempfindung", S. 295.
[28] Vgl. Schouten, „Die Tonhöhenempfindung", S. 296.
[29] Schouten, „Die Tonhöhenempfindung", S. 298.

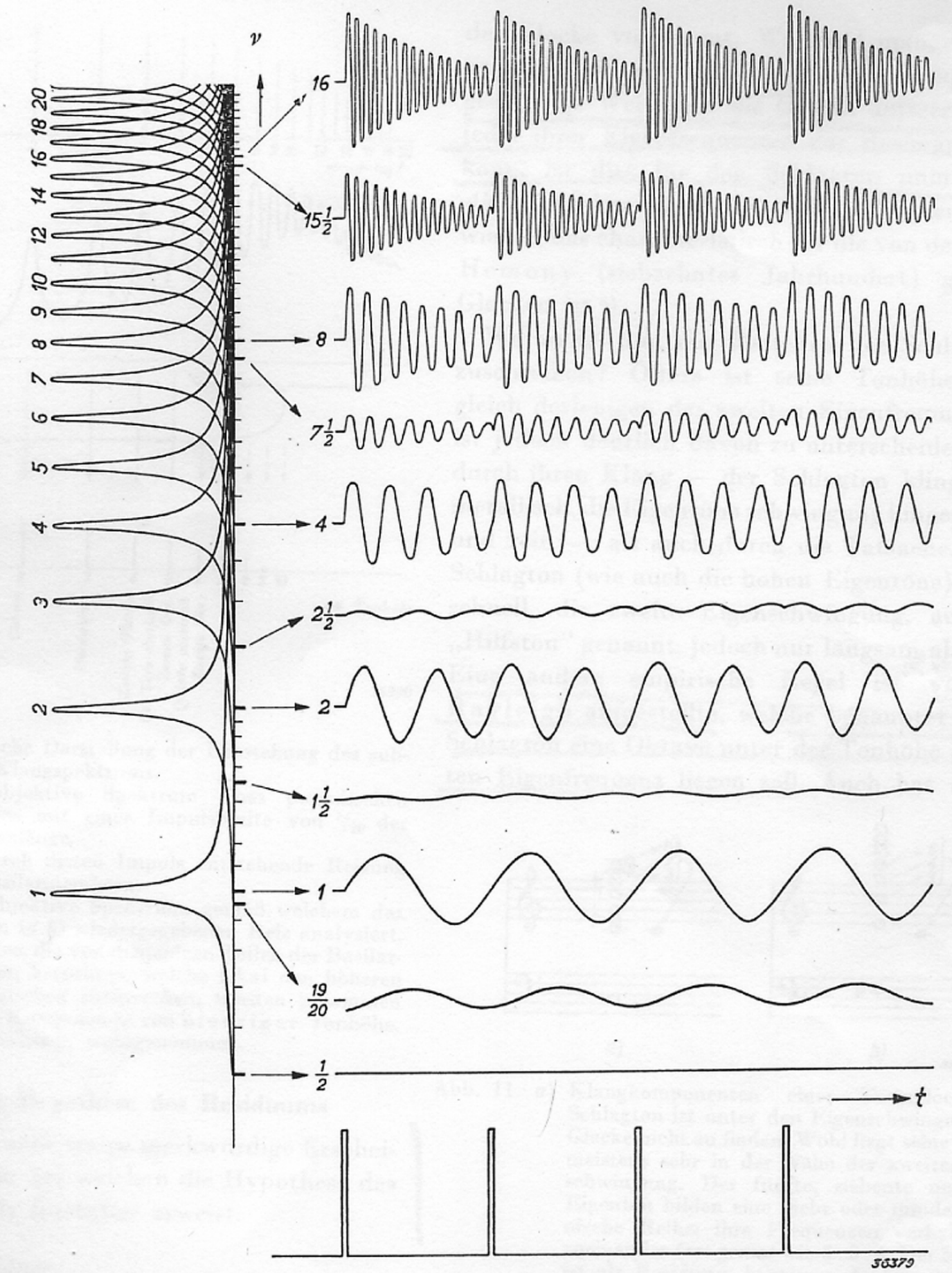
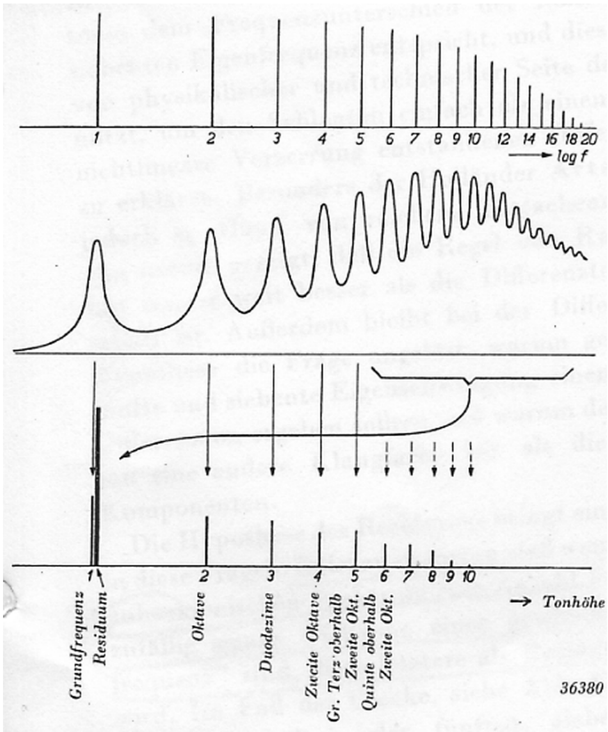


Abb. 9. Links über einer logarithmischen Frequenzskala Reizkurven, die für jede Harmonische der auf das Modell wirkenden Kraft (des periodischen Impulses) angeben, welche Resonatoren (Eigenfrequenz ν) in Bewegung gebracht werden und in welchem Maß. Die entstehende Bewegung ist hier für eine Anzahl Resonatoren (relative Eigenfrequenz $^1/_2$, 19/20, 1, $1^1/_2$, 2, $2^1/_2$, 4, $7^1/_2$, 8, $15^1/_2$, 16) gezeichnet. Man sieht, daß im Gebiete der höheren Harmonischen, wo die Reizkurven einander stark überlappen, die Schwingung aller Resonatoren deutlich die Periodizität der Grundfrequenz zeigt.

Abb. 3.



bb. 10. Schematische Darstellung der Entstehung des subjektiven Klangspektrums.
a) Das objektive Spektrum eines periodischen Impulses mit einer Impulsbreite von 1/20 der Periodenlänge.
b) Die durch diesen Impuls entstehende Reizung der Basilarmembran.
c) Das subjektive Spektrum, gemäß welchem das Ohr den in b) wiedergegebenen Reiz analysiert. Die Reize, die von denjenigen Teilen der Basilarmembran herrühren, welche lokal den höheren Harmonischen entsprechen, werden zusammen als eine Komponente von niedriger Tonhöhe, das Residuum, wahrgenommen.

Abb. 4.

In einem anharmonischen Obertonspektrum wie dem der Glocke ist es – aus Sicht der physikalischen Akustik – Zufall, daß eine Anzahl von Frequenzen auftreten, die ganze Vielfache einer Grundschwingung sind, die es im Spektrum der Glocke gar nicht gibt, die aber als Residuum dieser Frequenzen hörbar wird.[30] Heute spricht man von „virtual pitch“ oder auch „missing fundamental“.[31]

5.

Eine Glocke ist also primär Klangfarbe, ihr akustisches Sein ist primär nicht durch die Tonhöhe bestimmt, sondern durch jenes Gemisch von Obertönen, die für die Klangfarbe zuständig sind.

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30 Vgl. Schouten, „Die Tonhöhenempfindung“, S. 302.
31 Bill Hibbert, „The Strike Note of Bells – an old mystery solved“, *The Ringing World* 20 (2003), S. 586.

Der Grundton der Glocke ist ein Produkt der Klangfarbe. Ich will es nicht allzusehr zuspitzen und die Glocke als Dekonstruktion der abendländischen Schallkultur bezeichnen, aber man kann trotzdem soviel sagen, daß eine Glocke Obertonschwingungen ohne Grundtonschwingungen hat (was den Begriff „Oberton" eigentlich sinnlos macht). In ihr schwingen Teiltöne mit, ohne daß es jenen Ton gibt, der die Rede von einem *Mit*-Schwingen rechtfertigen würde. In ihrem Klang geht das Sekundäre dem Primären voraus, ja, das Primäre, der Grundton, das Fundament der Tonhöhe, wird allererst durch seine Obertöne, seine Teiltöne projiziert. Teiltöne sind Teil von etwas, das sie erst hervorbringen.

Was zwischen Signalanalyse und Kulturgeschichte vermittelt, ist die Lacansche Trias von Realem, Imaginärem und Symbolischem, die das Dispositiv der Glocke perfekt bestimmen. Das Symbolische ist die buchstäbliche Ordnung, in der die Glocke angeschrieben wird, in der sie nach ihrer Tonhöhe und ihrem Glockenprofil klassifiziert wird (Oktavglocke, Septimglocke, Sextglocke, Nonglocke).[32] Das Symbolische ist im Fall der Glocke ein Effekt des Imaginären, das heißt, der Schlagton oder Grundton der Glocke wird allererst im Imaginären produziert. Wortwörtlich ist es das Imaginäre, in dem, um mit Goethe zu sprechen, „der Schall zum Ton sich rundet", insofern nicht etwa Lacanianer, sondern nüchterne Physiker vom „imaginären Grundton" oder „virtual pitch" sprechen. Elektroakustiker vom Ende des 20. Jahrhunderts sprechen auch von „spektraler Gestaltwahrnehmung" (so Terhardt und Seewann 1984). Das Symbolische ist aber auch das Signal, welches der Schlag der Turmglocke ist, der Ruf, der die Menschen über die Grenzen der Pfarrgemeinde hinaus zur Versammlung ruft, zum Gotteswort, zum Feuer, zum Feind. Das Reale der Glocke ist schließlich das, was sich unmöglich anschreiben läßt und was erst technische Medien, Tonbandgeräte und Harmonic Analyzer aufzeichnen und verarbeiten können: das Reelle der absoluten Frequenzen, das im Fall der Glocke von einem „missing fundamental", einem mangelnden Fundamental,[33] gekennzeichnet ist, das psychoanalytisch nichts anderes ist als ein fundamentaler Mangel. Insofern das Klangspektrum einer Glocke durch diesen fundamentalen Mangel gekennzeichnet ist, besteht ihr Klangspektrum also nur aus Obertönen. Insofern die Obertöne aber vor allem die Klangfarbeninformation transportieren, ist der Erzklang reine Klangfarbe, Amplitude und Nachhallzeit. Folglich ist die Glocke ein Schallerzeuger, bei dem die Tonhöhe durch die Klangfarbe erzeugt wird.

Der zerstückelte Körper des Klangs geht der imaginären Ganzheit nicht nur voraus, sondern jener bringt diese allererst hervor, als ob das Imaginäre bereits auf physiologischer Ebene lokalisiert wäre, als ob das Ohr das Subjekt durch Bildung des Residuums vor dem Grausen eines zerstückelten Körpers schützen wollte. Filtert man das Residuum mittels Tiefpaß heraus, stellt sich im Ohr der Wahnsinn des Realen her.

Die Register des Imaginären und des Realen bezeichnen auch präzise die methodische Differenz zwischen musikwissenschaftlicher Campanologie, die in der auditiven Methode den Königsweg zu campanologischer Tonhöhenerkenntnis sieht, und experimenteller Akustik, die sich Medientechniken von der Drosselkette bis zum digitalen Harmonic Analyzer bedient. Musikalische Kultur und Experimentalkultur scheiden sich an der Frage des Erzklangs. Während Glockenforscher, die aus der Musikwissenschaft kommen und stolz auf ihr Gehör sind, darauf

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32 Vgl. Weissenbäck und Pfundner, *Tönendes Erz*, S. 7.

33 In der englischen Literatur zum Schlagtonproblem ist die Rede einfach vom „missing fundamental". Vgl. Hibbert, „The Strike Note of Bells", S. 586.

insistieren, daß der Schlagton von „jedem musikalischen Menschen" gehört wird und „unbedingt als musikalisch reale Tatsache gewertet werden (muß),"[34] urteilen andere wie Johannes Biele, der Schlagton sei ein „imaginäres Tongebilde."[35] Für Musikwissenschaftler hingegen ist wiederum klar, daß Physiker nur deswegen die reale Existenz der Schlagtonhöhe negieren, weil Physiker generell „ohne gutes musikalisches Gehör"[36] sind. Der musikwissenschaftliche Diskurs des Imaginären fußt am Ende auf dem Urteil der Überlegenheit bürgerlicher musikalischer Hochkultur.

Mit den Flächentönern des Blues und des Jazz und mit der Elektrifizierung der Musikinstrumente durch die Rockmusik wurde nicht nur die buchstäbliche Ordnung der abendländischen Musik gesprengt. Mit Flächentönern, elektrischen Verzerrungen, Rückkopplungseffekten und dem Moog-Synthesizer ergriffen auch andere Soundkulturen von unseren Ohren Besitz – was unter anderem auch in den sechziger Jahren daran zu erkennen war, daß verschiedene Gruppen wie die Beatles oder Pink Floyd nicht nur zu Glocken, sondern auch bewußt zu asiatischen Instrumenten wie Sitar oder Gong griffen. Und es ist in diesem Kontext signifikant, daß Claude Lévi-Strauss an den Anfang seines großen Werkes über die Mythen der südamerikanischen Indianer eine lange Betrachtung über die musique concrête Pierre Schaeffers und die serielle Musik von Pierre Boulez stellte. Als wäre das Denken des Anderen erst durch die zusammengeschnittenen und verfremdeten Tonbandaufnahmen von Geräuschen einerseits und andererseits durch eine Kompositionsmethode eröffnet oder ermöglicht worden, „in der es keine vorgefaßte Tonleiter mehr (gibt)".[37]

Aber die Turmglocken haben immer schon einen Pakt mit diesem Anderen der europäischen Klangkultur hergestellt. Um über die Grenzen ihrer Pfarrgemeinden hinweg die Christenheit zu versammeln, paktierte DAS Wort mit dem Realen, der Logos mit dem Alogischen. Sein anharmonischer Klangfarben-Schall, der den europäischen Menschen an seine Grenze beorderte (Grenze der Vernunft, des Krieges, seiner irdischen Endlichkeit), hatte schon immer den Abgrund der buchstäblichen Ordnung der europäischen Soundkultur aufgerissen.

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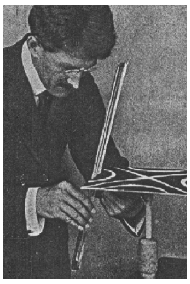
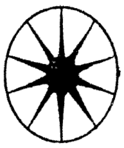
[34] Weissenbäck und Pfundner, *Tönendes Erz*, S. 11.
[35] Johannes Biehle, „Die Analyse des Glockenklanges", *Archiv für Musikwissenschaft* 1/2 (1919), S. 289-312.
[36] Weissenbäck und Pfundner, *Tönendes Erz*, S. 13.
[37] Vgl. Claude Lévi-Strauss, *Mythologica I: Das Rohe und das Gekochte*, übers. von Eva Moldenhauer, Frankfurt/M.: Suhrkamp, 1976, S. 40-42, Zitat auf S. 42.

Klangfiguren (a hit in the lab)

Peter Szendy

If Ernst Florens Friedrich Chladni's name is remembered today, if we have some memory of it, it is largely due to his famous sound patterns (*Klangfiguren*). They were a real hit, if I may say so, not only in the history of acoustics, but also in the history of aesthetics and philosophy. Their indirect consequences and echoes are, moreover, very far-reaching, well beyond the confines of the scientific laboratory, maybe into our everyday life. They might even constitute the nucleus from which, with some mediations which we are about to read, the modern biopolitical effects of music evolved,[1] in the form of hits (classical or popular) used to subject individuals and their memories.





Chladni produced his *Klangfiguren* by means of a violin bow which he used to cause a vibration in a metal or glass plate duly fixed in some point of its surface. "The various vibrating movements in a plate," he wrote in his *Treatise on Acoustics*,[2] looking back on the experiments he made starting from 1785, should "have different aspects, when one spreads some sand on its surface" (ibid., vii).

Seemingly astonished at his own patterns, as were all those who were later to admire them, he added: "In this way, the first pattern that I saw before my eyes, on the circular plate, looked like a star with 10 or 12 rays [...]." The patterns, then, were the traces of a rustling in the resonant body; they were the marks of its quivering. The physicist Johann Wilhelm Ritter described them, some years later (in 1810), as "writing in fire" (*Feuerschrift*[3]). Thus, as the sand is scattered along the nodal lines, where the amplitude of the vibrations remains minimal, it outlines a pattern, that follows the structure of the plate and the way it was made to resonate. One could also see it as a radiography of its properties. Or, if I may use this word in its most literal sense, as its *phonography*.

Adorno did not miss the point, when, in his essay dedicated to "The Form of the Record," he saw in Chladni's sound patterns a kind of primal gramophony:

> If the notes have only been [the] mere signs [of music], now, thanks to the curves of the needle on the phonograph records (*Nadelkurven*), music comes crucially close to its true scriptural character (*ihrem wahren Schriftcharakter*). Crucially (*entscheidend*), because this writing has to be acknowledged as authentic language (*echte Sprache*), in that it loses its mere sign-nature (*ihres bloßen Zeichenwesens*): it is indissolubly linked to the sound that dwells in this, rather than in any other groove (*der dieser und keiner anderen Schall-Rinne innewohnt*). If it is true that, with records, the productive force of music has been extinguished, [...] for this same

1 On biopower and biopolitics, see Michel Foucault, *"Il faut défendre la société." Cours au Collège de France, 1975-1976*, Paris: Seuil/Gallimard, 1997, p. 216ff.

2 A French version of this treatise was published in Paris by Courcier in 1809.

3 See Johann Wilhelm Ritter, *Fragmente aus dem Nachlasse eines jungen Physikers*, (Heidelberg: Mohr und Zimmer, 1810) Facsimile, Heidelberg: Schneider, 1969, p. 227ff. (Quoted by Walter Benjamin in his *Origin of German Tragic Drama*, Frankfurt/M.: Suhrkamp, 1974 [=*Gesammelte Schriften*; I.1], p. 387.)

> reason, records transform the newest sound of ancient feelings into an archaic text for a coming knowledge (*so verwandeln sie dafür den jüngsten Klang alter Gefühle in einen archaischen Text kommender Erkenntnis*). [...] Physics play an important part here; above all, Chladni's sound figures, [...] that Johann Wilhelm Ritter already described as primal, scriptural images of sound (*die schriftgemäßen Urbilder des Klanges*).[4]

Through the long history of their readings and interpretations, Chladni's sound figures seem to announce phonography. They seem to pave the way for these recordings (*Grammophonplatten*) that, as Adorno writes in this same essay, made even "passage and memory" easy to use ("handy" might be the best translation for his German term, *handlich*).

What does it mean, then, to *handle memory*? To *manipulate* memory, as if it were the object of an experiment?

More precisely, Adorno refers to "memory, as it inescapably and yet indefinitely sticks, as mere sound, to the barrel organs" (*Erinnerung, wie sie den Drehorgeln als bloßer Klang zwangsvoll, doch unbestimmt anhaftet*). What seems to have become subject to manipulation, to organized handling or maintenance, is a memory bindingly linked to one sonority (uniquely attached to *this* sound, and to no other), while remaining undefined, indefinitely ready to host everything that can be poured into it. And the instrument that Adorno presents as the emblem of such a handy memory is a rotating reservoir of corny old tunes, equipped with a handle that evokes the film projectors of the thirties as well as the early phonographs. For it is the spinning of the repeated tune that Adorno seems to have in mind, rather than any specific tone colour, when he speaks of the "mere sound" of the barrel organs. A sound, then, characterized by its being bound to returning turns and tropes.

One thinks of Schubert's *Leiermann*, this beautiful song on a poem by Wilhelm Müller: "Over there beyond the village stands a hurdy-gurdy man, / and with numb fingers he winds as best as he can." (*Drüben hinterm Dorfe steht ein Leiermann, / Und mit starren Fingern dreht er, was er kann.*) The "mere sound" of memory Adorno has in mind – the sound of a song that, like a merry-go-round, repeats the course of history without disturbing it – could be the ancestor of our hit songs, an archaic form of these mass products poured out on the culture industry market. Readily usable forms of *Erinnerung*, handy souvenirs that we manipulate to weave our experience of time and (or as) mourning.

Is this the future that Chladni's sound patterns announced with their *Feuerschrift?*

Let us turn the handle of memory and go back in time.

Before Adorno, among all the voices that carried and transmitted Chladni's name through the nineteenth century,[5] Nietzsche had referred to the acoustic patterns in *On Truth and Lie in an Extra-Moral Sense:*

> One can imagine a man who is totally deaf and has never had a sensation of sound and music: he will gaze with astonishment at Chladni's sound figures in sand, he will find their causes in the vibrations of the string and will consequently swear that he must know what men mean

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4 Theodor W. Adorno, "Die Form der Schallplatte," in: idem, *Musikalische Schriften VI*, Frankfurt/M.: Suhrkamp, 1984 [=*Gesammelte Schriften*; 19], p. 533.

5 See, among many others, Hegel, *Encyclopedia of Philosophical Sciences* (§ 300, "Der Klang"), and Schopenhauer, *Welt als Wille und Vorstellung* (III, § 52).

> by "sound"; it is this way with all of us concerning language. We believe that we know something about the things themselves when we speak of trees, colours, snow, and flowers; and yet we possess for things nothing but metaphors, which correspond in no way to the original entities.[6]

For Nietzsche, then, Chladni's drawings are the figure, the trope of a generalized metaphoricity: traces that somehow allow us to see, in an *image*, that there is nothing but images, without any stable origin.[7]

Reading these lines on man's instinctive urge to create metaphors, one cannot help thinking of what Nietzsche says about popular songs – the ancestors, as it were, of our hit songs. Not unlike Adorno, Nietzsche refers to a primal gramophony of the song, one that repeatedly produces written images of itself:

> But to begin with, the folk song is for us the musical mirror of the world, the primordial melody, which seeks for a parallel dream image of itself and expresses this in poetry. The melody is thus primary and universal, for which reason it can undergo many objectifications, in several texts. [...] Melody gives birth to poetry from itself, over and over again; this is what the strophic forms in the folk song indicates to us: I have always observed this phenomenon with astonishment, until I finally came up with this explanation. [...] [one] will find countless examples of how the continually fecund melody emits fiery image-sparks all around.[8]

Nietzsche is as astonished in front of these ever-changing image-sparks (*Bilderfunken*) as his deaf man in front of Chladni's patterns. And if Chladni's patterns are the *figures* of the arch-metaphorical (*urbildlich*) source of language, the *Bilderfunken*, in turn, are the metaphors of all the tropes that the melody gives birth to, when it returns and repeats itself, as if it were played on a barrel organ.

Bilderfunken: it is impossible not to hear, in this word or image, an echo of the first verse of Schiller's Ode to Joy, that Beethoven chose for the finale of his Ninth. *Freude, schöner Götterfunken*, says the famous line sung by the chorus, in this symphony that Nietzsche quotes as a way of *imagining* the Dionysiac.[9]

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6 *Über Wahrheit und Lüge im außermoralischen Sinne* (my translation): "Man kann sich einen Menschen denken, der ganz taub ist und nie eine Empfindung des Tones und der Musik gehabt hat: wie dieser etwa die chladnischen Klangfiguren im Sande anstaunt, ihre Ursachen im Erzittern der Saite findet und nun darauf schwören wird, jetzt müsse er wissen, was die Menschen den „Ton" nennen, so geht es uns allen mit der Sprache. Wir glauben etwas von den Dingen selbst zu wissen, wenn wir von Bäumen, Farben, Schnee und Blumen reden, und besitzen doch nichts als Metaphern der Dinge, die den ursprünglichen Wesenheiten ganz und gar nicht entsprechen."

7 Cf. Jacques Derrida, "La mythologie blanche", in: *Marges de la philosophie*, Paris: Éditions de Minuit, 1972, p. 313: "[une] généralisation de la métaphoricité par la mise en abyme d'une métaphore déterminée."

8 *Die Geburt der Tragödie*, § 6 (my translation): "Das Volkslied aber gilt uns zu allernächst als musikalischer Weltspiegel, als ursprüngliche Melodie, die sich jetzt eine parallele Traumerscheinung sucht und diese in der Dichtung ausspricht. Die Melodie ist also das Erste und Allgemeine, das deshalb auch mehrere Objectivationen, in mehreren Texten, an sich erleiden kann. [...] Die Melodie gebiert die Dichtung aus sich und zwar immer wieder von Neuem; nichts Anderes will uns die Strophenform des Volksliedes sagen: welches Phänomen ich immer mit Erstaunen betrachtet habe, bis ich endlich diese Erklärung fand. [...] [man] wird unzählige Beispiele finden, wie die fortwährend gebärende Melodie Bilderfunken um sich aussprüht. [...]"

Among the many image-sparks that Beethoven's Ninth has thrown around itself, while turning and returning for almost two centuries, there is Stanley Kubrick's 1971 film, *A Clockwork Orange*.

Unfortunately, I have to relinquish, any attempt at in-depth analysis of this masterpiece. But I would like to evoke, if only briefly, two contrasting sequences that revolve around the Ninth and "the old Ludwig van", as Alex puts it in the movie.

Alex, the main and well-known character of the film, loves blood, torture, and rape – he cynically describes sexual intercourse as "the old in-out, in-out." Returning home after a whole night of what he calls "a bit of the old ultraviolence," he sits down in front of his cassette player and thinks to himself: "It was a wonderful evening. And what I needed now to give it the perfect ending, was a bit of the old Ludwig van."

Let us "viddy" (meaning *to see*, in Alex's strange idiom, the "Nadsat," a mixture of English and Russian borrowed from Anthony Burgess' novel that inspired the film), let us "viddy" the images he sees while the second movement of the Ninth plays in his room. "Oh, bliss," Alex exclaims, "bliss and heaven"; and he adds, in his typically florid language: "It was gorgeousness and gorgeosity made flesh. It was like a bird of rarest spun heaven metal. Or like silvery wine flowing in a spaceship [...] As I slooshied [as I listened, in Nadsat], I knew such lovely pictures [...]" He indeed "viddies" lovely figures or tropes of the good old ultraviolence: the hanging of a woman viewed from underneath, his own bloody vampire-teeth, and people crushed by crumbling stones. A real explosion of sparkling *Bilderfunken*...

After Alex's imprisonment for murder, and during his medical treatment against violence, the function of the Ninth changes radically. Dr. Branom, who supervises his experimental cure, explains to him the treatment he is going to receive:

> Dr. Branom: "It's quite simple, really. We're just going to show you some films." Alex: "You mean like going to the pictures?" Dr. Branom: "Something like that." Alex: "That's good. I like to viddy the old films now and again."

Alex, then, goes to the movies. And we will follow him briefly, going to the movies inside the movie.

At first, Alex enjoys the "very good, professional piece" he is forced to watch, a film "like it was done in Hollywood," with blood flowing ("the red, red vino on tap," as his voice-over says). But, very soon, as a consequence of the injections given to him for his treatment, he begins to feel sick in front of the *Bilderfunken*. And the next day, while "viddying" images of World War II and the Nazi troups, he painfully recognizes the sound-track that accompanies them: "Ludwig van, Ninth Symphony, fourth movement," played by a synthesizer. Alex cries out in pain: "Stop it! Please, I beg you! It's a sin! [...] Using Ludwig van like that. He did no harm to anyone. Beethoven just wrote music." But the two doctors agree that Alex has to go through the treatment and that, with

9 *Die Geburt der Tragödie*, § 1: "If someone were to transform Beethoven's *Ode to Joy* into a painting and not restrain his imagination when millions of people sink dramatically into the dust, then we could come close to the Dionysian." ("Man verwandele das Beethoven'sche Jubellied der 'Freude' in ein Gemälde und bleibe mit seiner Einbildungskraft nicht zurück, wenn die Millionen schauervoll in den Staub sinken: so kann man sich dem Dionysischen nähern.")

Beethoven, he "can't be helped." As one of them comments: "Here's the punishment element perhaps."

By a sort of accident in the medical treatment, the Ninth not only ceases to *produce* image-sparks (it has become the mere background score for pictures drawn from the dark archives of history), but embodies the remainder of a punitive dimension that cannot be cancelled by medication and experimental biopolitics.

In spite of all this brainwashing, we should not forget Chladni. With one last turn of the memory-handle, let me return, then, to where we started.

In 1787, Chladni explained, on the basis of his sound patterns, how various sounds coexist in the vibration of the same body. But this simultaneous presence of com-possible sounds, he said, cannot be reduced, in a Pythagorean way, to the overtones of a fundamental: there are also "inharmonic and irrational relationships," due to the irregularities of the vibrating body.[10] This is why Chladni dismisses the monochord, the instrument that was the basis of acoustic theory and calculation since Greek antiquity; as Chladni writes in the introduction to his *Treatise on Acoustics:* "a string is only one sort of sonorous body,"[11] among many others. This dismissal of the Pythagorean monochord and calculation is Chladni's revolution, his modernity. It opens the possibility of experimenting with *all* vibrating bodies, while his sound patterns allow us to see their complex vibrating structure.

When Goethe met Chladni, in 1803, he was very quick to grasp the modernity of such a theory. And he attempted to develop, on the basis of that newly discovered complexity, an explanation of the major and minor scales in music, as well as their *effects*. Thus, in his notes for a *Theory of Sound* (*Tonlehre*[12]), Goethe speaks of "discovering natural relationships different from those found on the monochord" (*Entdeckung anderer Naturverhältnisse als durchs Monochord*). This move, clearly inspired by Chladni, will eventually lead Goethe to a *dynamical*, rather than arithmetical, conception of the major and minor modes. In one of his letters of 1815, Goethe proposes the fascinating hypothesis of a "tone monad" that expands and contracts, provoking analogous effects in the hearing subject, driven to outward action or pulled together in the concentration on himself and his nostalgic memories; I quote in German:

> [...] wie der Durton aus der Ausdehnung der Monade entsteht, so übt er eine gleiche Wirkung auf die menschliche Natur, er treibt sie ins Objekt, zur Tätigkeit, in die Weite, nach der Peripherie. Ebenso verhält es sich mit dem Mollton; da dieser aus der Zusammenziehung der Monade entspringt, so zieht er auch zusammen, konzentriert, treibt ins Subjekt und weiß dort die letzten Schlupfwinkel aufzufinden, in welchen sich die allerliebste Wehmut zu verstecken beliebt.[13]

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[10] Ernst Florens Friedrich Chladni, *Entdeckungen über die Theorie des Klanges*, Leipzig, Weidmann, 1787, p. 71. In his outstanding study ("Il canto della natura. Herder, Goethe, Chladni e la monadologia musicale nel primo Romanticismo," *Intersezioni* 18/1 (1998), p. 99), Riccardo Martinelli comments: "A revolution: we are in front of non-Pythagorean acoustics [...]."

[11] Chladni, *Entdeckungen über die Theorie des Klanges*, p. 11.

[12] Cf. Johann Wolfgang Goethe, *Schriften zur allgemeinen Naturlehre, Geologie und Mineralogie*, Frankfurt/M.: Deutscher Klassiker Verlag, 1989 (=*Sämtliche Werke*; 25), p. 182.

[13] To Christian Heinrich Schlosser, a physician in Koblenz and a pupil of Schelling's (May, the 5th).

Reading these notes, if we do not take the reference to major and minor modes too literally, we can hear, in the aftermath of Chladni's sound patterns, the birth of a theory that announces the handiness of nostalgia and memory as diagnosed by Adorno, as well as the role played by Beethoven's Ninth in *A Clockwork Orange*, where it drives Alex to violent action. In this sense, the acoustic monadology, that Goethe imagined as a sort of dynamic calculation of forces, could be seen as the first step towards the experimentalization of sound effects and affects, towards a biopolitical musicotherapy of passions.

When Goethe speaks of expansion and contraction (or of the systole and diastole of the monad, with its corresponding effect on the human heart or lungs), one is reminded of Alex's words: *the old in-out, in-out*. For what is at stake, here, is already the in-out motion of an impulse that music creates in an experimentally controlled way, in order to subject the subject.

Alex could be the late image or icon of this power that I would call, with Foucault, a musical biopower.[14] Belonging to the century of *muzak* (an American company founded in 1922 to pipe music to various public places, on the basis of a rationalized system of stimulus codes[15]), Alex demonstrates the ultimate consequences of a musical theory of affects that was born in the aftermath of Chladni's sound patterns. This century, the 20th, to which we ourselves might still belong, sees the medically treated subject of experience subjugated by a hit song like the *Ode to Joy* and turned into a vibrating plate himself. A subject-plate, if I may say, whose experimentally provoked vibrations are used to measure his resistance and his nodal lines, with the old ultraviolence of the expansions and contractions that constitute his self.

The best commentary to this image or icon would no doubt be the following speech, made by Zell Miller, Governor of the State of Georgia, on the 13th of January, 1998. His Budget Address, as you will hear, echoes the latest American scientific research in the field. Let me quote, to conclude, a large excerpt of it:

> And while I'm on children, I want to tell you about another initiative I'm proposing and am very excited about. We know that a baby's brain continues to form after birth, not just growing bigger as toes and fingers do, but developing microscopic connections responsible for learning and remembering. [...] The new research on brain development in babies is unbelievable. [...] In October we had an early childhood development seminar for teachers, medical professionals, staff of our state agencies that work with children, and businesses with products and services for tiny customers. It was fascinating. Why am I telling you all this in a

14 See Michel Foucault, "Crise de la médecine ou crise de l'antimédecine?," in: *Dits et écrits*, vol. 2, Paris: Gallimard, 2001, p. 40ff. (where the limitless generalization of medical intervention is described in terms of "biohistory").

15 On *muzak*, see David Toop's article "Environmental Music", in: *Grove Music Online* (www.grovemusic.com), Oxford: Oxford University Press, accessed September 2006: "In 1922 George Owen Squier, a Michigan-born military officer who had conducted research into wireless systems, launched a company that would attempt to pipe music, advertising and public service announcements into homes and businesses. As well as foreseeing the late 20th-century home entertainment reality of cable communications, Squier coined the name Muzak, a fusion of the words 'music' and 'Kodak'. During the 1930s the Muzak company, based in New York City, began systematic broadcasting to hotels, clubs, restaurants and shops. This programme of centralized transmission came to be rationalized into a system of stimulus codes, supported by scientific studies that demonstrated links between music, productivity and safety in factories."

> speech that is already far too long ? Because I want to propose something extraordinary that I don't think any other state does. And it is this. [...] There is research that links the study of music to better school performance and higher scores on college entrance exams. There's even a study called the "Mozart effect" that showed after college students listened to a Mozart piano sonata for 10 minutes, their IQ scores increased by nine points. [...] So I propose that the parents of every baby born in Georgia – over a 100,000 a year – be given a cassette or CD of music to be played often in the baby's presence. It's not a big ticket item in the budget – only $105,000 – but I believe it can help Georgia children to excel. [...] For instance, here's one that a Georgia baby might hear. That, of course, is Beethoven's "Ode to Joy." Now don't you feel smarter already? Smart enough to vote for this budget item, I hope.[16]

"Real horrorshow", as Alex himself would say, in his florid idiom.

16 "Remarks by Governor Zell Miller : FY 99 Budget Address 1/13/98", http://www.state.ga.us/archive/governor/tspeech.cgi, accessed September 2006.

Sound Objects

Julia Kursell

The aim of this paper is to suggest "sound object" as a notion for the discussion of the history of research on sound and hearing. It will be defined for a specific historical situation of research on acoustics, namely Hermann von Helmholtz's research on vowel sounds. Research on sense perception underwent a change after 1800. The new organization and positioning of the subject in the aftermath of Kant's subject-centered philosophy went with the emergence of a new, physiological science of sense perception.[1] If before the dichotomy of subject and object had been correlated to the distinction between inside and outside, now the objects of sense perception were no longer considered to be outside of the subject, but simply the result of perception itself. While perception thus obtained an objectiveness of its own, at the same time, this move seemingly restricted the investigation of these objects to introspection.

Research on the physiology of the senses thus encountered the new problem of defining a double object of investigation. The function of the sense organs *and* their products had to be described. This brought about abundant descriptions of phenomena such as the afterimages of light and color that are seen with closed eyes. However, the science of sense perception did seek to expand its methodology beyond introspection. Experimental sense physiology integrated sense perception into set-ups that not only modified sense perception with extraneous devices, but also reified the functions of the sense organs outside the body. In this respect, research into the various senses differed.

For the history of research into vision, the break that experimental physiology brought for perception can be described in terms of a discovery of a new objectiveness of the inside. Before 1800, vision had been considered to provide "insight" into an objective world. In the early 19th century, this idea of a projection through the eye was given up and replaced by a concept that understood perception as yielding its own objects. For hearing, the situation was somewhat different. Research on the physiology of the ears made it necessary to break with the earlier concept of hearing as a matter of psychology. Hearing had been considered to relate the subject to the world in a subjective way. To claim the objectiveness of aural perception would therefore pose slightly different problems. As will be shown, the reification of the functions of hearing for experimentation was particularly relevant in this context. Systematic research on hearing started in the mid-1850s, with Hermann von Helmholtz as the main figure in the field. His research was based on the assumption that sound must be understood as what is heard rather than what causes hearing. Theories of the physics of vibrating bodies were unable to explain why sound was heard in the way that it was. Helmholtz formulated the first coherent physiological theory about the functioning of the ear, involving the state of the art in anatomy, mechanics, mathematics, linguistics, and music.

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1 Cf. Jonathan Crary, *Techniques of the Observer. On Vision and Modernity in the Nineteenth Century*, Cambridge, MA: MIT Press, 1990, pp. 69-70 and passim.

The shift to a new understanding of acoustics as physiological rather than physical affected the idea of sound profoundly. Therefore, Helmholtz's experimental research on hearing is taken as the point of departure for this paper. His research is then contextualized with the history of research on vowels, starting with the construction of speaking machines in the late 18th century and continuing on to experimental acoustics in the 1830s. The notion of the sound object will then be used to describe the double function of sound in the research of hearing, where the experimental set-ups both reify the functions of the ear and the products of perception.

The notion of a sound object alludes to French composer, radio author, and theoretician Pierre Schaeffer. In the 1950s and 1960s, Schaeffer developed a theory of music that would give any sound the status of a meaningful musical entity. He introduced the notion of "*objet sonore*" to describe what he obtained with the help of a magnetic tape.[2] Although the tape as the *conditio sine qua non* of the *objet sonore* would give the best explanation for what he meant by his term, he himself refrained from identifying the sound object simply as a bit of tape. Instead, he defined the sound object *ex negativo*: the sound object was not the instrument recorded on the tape, nor was it the tape or bit of tape, because the same bit of tape could contain a wealth of sound objects. Nor was the sound object constituted from the psyche because it did not depend on the individual listener.

Schaeffer conceived of a sound object as something that is heard under certain well-defined conditions. These conditions were shaped by the magnetic tape, which provided a reference that was common to many experiences of hearing. In Schaeffer's treatise on musical objects, the tape just provided one element of Schaeffer's argument, which enabled him to speak of comparable hearing experiences rather than dealing with the tape's abilities to manipulate sound. As will be shown in the following, Schaeffer's concept can be traced back to experimental research in sense perception. However, in the case of hearing, the difficulty of defining the objects of perception is even more apparent than with visual perception. Sound fades, and the objects of hearing have to be mediated by some technical support if they are to be subjected to enquiry. Although this is no less true for vision or touch, in many recent accounts in the history of these subjects, it was the persistent images or touchable things that were referred to as objects rather than the intangible objects of perception. And although the confusion of images – in the strict sense of pictures, paintings, illustrations – with the objects of visual perception has been rightly criticized,[3] the difficulties inherent in the lack of persistence of any sounding object have to be taken into account. The discourse concerning hearing has been shaped by the necessity of coping with the elusiveness of sound.

1. Experiments on hearing

Helmholtz started work on the physiology of hearing in 1856. In his first publication on the topic, he stated that, for sense perception, the distinction between subject and object had to be revised.[4]

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2 Cf. Pierre Schaeffer, *Traité des objets musicaux. Essai interdisciplines*, Paris: Seuil, 1966.

3 Cf. Crary, *Techniques of the Observer. On Vision and Modernity in the Nineteenth Century* for both a history of vision that draws the attention to the unstable objects of perception and for a critique of the confusion of images with the objects of vision.

4 Cf. Hermann v. Helmholtz, "Ueber Combinationstöne," *Annalen der Physik und Chemie* 99 (1856), pp. 497-540.

He reported that physicists had distinguished between objective and subjective phenomena – "objective" meaning that physics could give an explanation of a phenomenon, while "subjective" implied that the phenomenon in question was a figment of the imagination. This distinction drew a line between inside and outside the body; physical acoustics investigated the generation of sound waves and their movement through the air, while the phenomena that were heard were considered to be subjective and therefore the subject matter of psychology. In this distinction there was no room for the physiology of hearing. In contrast, Helmholtz expanded the application of the laws of mechanics to the human body. He claimed that physical phenomena, such as resonance, could occur within the ear and that it was through these physical phenomena that hearing functioned. So, if a tone was heard whose existence could not be proven by measurement this did not mean that it was mere fancy, but that it might have its source in the organ of hearing. Having observed that, with the help of resonance, sounds could be analyzed into their components, Helmholtz postulated that such an analysis happens in the ear. Small bodies in the inner ear, he assumed, were capable of resonating and thus analyzing incoming sounds.

In a series of simple experiments involving a piano and the voice, he demonstrated how this analysis by resonance would work. The experiment required pressing a single key softly to lift the damper without producing a tone. Singing towards the piano a note whose pitch was identical to the pitch of the string would cause the string to resonate. Such experiments had been made long before. To excite a string by resonance rather than by touch was considered in the 18th century to be an entertaining trick.[5] In experimental physiology, this simple experiment took on a new meaning. As became clear from further experiments with this "set-up," the piano functioned as a reification of the inner ear. A second experiment required lifting the dampers of all strings and placing little strips of paper on them. When a note was sung into the open body of the piano, the strips would fall off of some strings, while others would remain still. As this experiment showed, a single note excited not only one, but several strings. And if one were to sing a different note, different strips would fall. The piano thus proved capable of differentiating between notes, i.e., between compound sounds, of different pitches.

According to the resonance theory, the ear would react to incoming sounds as distinct combinations of resonating bodies were excited. Each of the resonating bodies in the ear was believed to be tuned to a specific frequency. The cochlea in the inner ear was considered to comprise a broad range of tuned anatomical parts. In the experiment, the strings in the piano played the role of those anatomical parts. Again, the assumption that hearing might rely on resonance was not new, but former theories had assumed that resonance acted directly on the nerves.[6] Helmholtz, however, was able to refer to recent microscopic studies that allowed him to suggest appropriate structures in the inner ear that would allow for resonance. The "sensations of tone," he assumed, were the simple elements that constituted aural perception. Consequently Helmholtz proposed a new definition of tone that made it necessary to distinguish between "physical" and "musical" tones.

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5 For resonance experiments before Helmholtz cf. Robert T. Beyer, *Sounds of Our Times. Two Hundred Years of Acoustics*, New York: Springer, 1999, p. 14.

6 On the earliest theories of the ear as a resonating instrument cf. Giuseppe Gradenigo, "Est-ce vraiment à Helmholtz qu'on doit attribuer la théorie sur l'audition qui porte son nom?," *Archives italiennes de Biologie* 69 (1919), pp. 33-47, who does not, however, acknowledge the difference between resonating nerves and resonating bodies which transmit their excitation to the nerves.

A physical tone would thus be a simple vibration with a sinusoidal shape, whereas a physical sound would be a compound of several sinusoidal vibrations. A musical tone, correspondingly, would be *perceived* as simple, although it could consist of several "physical tones," while a chord, which was composed of many musical tones, would be *perceived* as a harmonious multitude. The distinction between perception and sensation, in turn, served to connect perception to the mechanics of resonance: one "sensation of tone" corresponded to the simple, physical tone that would excite one resonating body in the cochlea. Consequently the musical tone in most cases was shaped by several sensations. What was "heard" in the sense of "perceived" could be broken down into what was measured and formally expressed.

If, in the first two experiments described here, the use of the voice seemed incidental, another experiment showed that the use of the voice was at least of some advantage. In this experiment, the attention was focused on sound color. With all the dampers lifted, one could sing a vowel in any pitch of the piano and hear the vowel sound resonate. If an *O* was sung, something like an *O* would resonate in the body of the instrument, the vowel *A* would give a resonance of *A*, and so forth. Only *I* would resonate less well, Helmholtz reported. This showed that resonance conveyed not just different pitches but also different degrees of excitement. In other words, the resonance theory could explain the distinction between pitch and intensity.

From this it followed that the differentiation of sound colors could be explained as combinations of these two parameters. A voice singing different vowels turned out to be the ideal object to verify this. To compare the resonance of five different sounds one would have needed five different instruments and a few people capable of playing them. These experiments showed that, in contrast to any other "musical instrument," the voice was capable of modifying both its pitch and its sound color independently. More precisely, the voice is the only sound source that can alter its pitch, yielding at the same time a systematic variation of sound color.

2. History of vowel research

Sound color had escaped the attention of philosophers, Leonard Euler remarked in one of his *Letters to a Young German Princess* in 1761. As he explained to his addressee, we discriminate the loudness of tones easily. Also, music has taught us that tones vary in their pitch, and it is on this differentiation that musical harmony is based. There is, however, another property of sounds that we often experience when music is played: "Two sounds may be of equal force, and in accord with the same note of the harpsichord, and yet very different to the ear. The sound of a flute is totally different from that of the French horn, though both may be in tune with the same note of the harpsichord, and equally strong."[7] The human voice, "that astonishing master-piece of the Creator,"[8] could produce this variety of sounds simply by modifying the shape of the mouth. Although the consonants involved more "organs" than just the mouth cavity, such as lips, tongue, and palate, Euler claimed that it should be possible to construct a machine that could articulate the sounds of language: "The thing does not seem to me impossible."[9]

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7 Leonhard Euler, *Letters of Euler on Different Subjects in Natural Philosophy: Addressed to a German Princess*, ed. by David Brewster, Edinburgh et.al.: Tait et.al., vol. 2, pp. 67-70, quote on p. 68.
8 Ibid., p. 69.
9 Ibid., p. 70.

Subsequently, a number of attempts were made to construct such a device.[10] In 1780, Danish physician and physicist Christian Gottlieb Kratzenstein won a prize awarded by the Imperial Academy of St. Petersburg for the successful construction of organ pipes that could imitate the vowels of language.[11] Wolfgang von Kempelen constructed a talking machine around 1780, an apparatus that emitted entire phrases in various languages. In this machine, a bellows sent air through a variety of devices that would carry out different actions of articulation, such as phonation and the formation of the vowels and sonorous and noisy consonants. In the end, the air passed through a malleable leather bell whose shape could be changed with the hand, thus changing the quality of the "vowel" sounds. The sentences would come out most convincingly when there were few consonants in them, and the vowels could be discriminated best when they followed each other in quick succession, Kempelen reported in 1791.[12] He even claimed that any artificially produced vowel would resemble the German *A* when it sounded for a while. The phonation device in the machine could produce only one pitch – Kempelen did not intend his machine to sing. Nevertheless he noticed that a sequence of vowels would sound like a melody. This observation was, however, a byproduct of his work for which he did not provide an explanation.

By the 1830s the earlier attempts to imitate speech had attracted the attention of experimental researchers. The physicist Robert Willis conducted a series of experiments on vowel sounds and published his results in 1830. He criticized his forerunners for considering vowel sounds only with regard to articulation. "Kempelen's mistake, like that of every other writer on this subject, appears to lie in the tacit assumption, that every illustration is to be sought for in the form and action of the organs of speech themselves, which, however paradoxical the assertion nay appear, can never, I contend, lead to any accurate knowledge of the subject."[13] In a long article, "On Vowel Sounds, and on Reed-organ Pipes," Willis emphasized that the means to produce the sounds did not have to resemble the organs of speech. One of the experiments he described in his article broke completely with the idea of such similarity. While the article is mostly about air columns in reed pipes, this experiment did not involve any wind instrument. Holding a piece of watch-spring

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10 Accounts of the history of speaking machines are given by Gerold Ungeheuer, *Elemente einer akustischen Theorie der Vokalartikulation*, Berlin, Göttingen, Heidelberg: Springer, 1962; idem, "Über die Akustik des Vokalschalls im 18. Jahrhundert. Der Euler-Lambert-Briefwechsel und Kratzenstein," *Phonetica* 40 (1983), pp. 145-171; Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination*, Princeton, N.J.: Princeton University Press, 1995, pp. 179-220 (*Vox Mechanica*: The History of Speaking Machines); Brigitte Felderer, "Stimm-Maschinen. Zur Konstruktion und Sichtbarmachung menschlicher Sprache im 18. Jahrhundert," in: *Zwischen Rauschen und Offenbarung. Zur Kultur- und Mediengeschichte der Stimme*, edited by Friedrich Kittler, Thomas Macho and Sigrid Weigel, Berlin: Akademie Verlag, 2002, pp. 257-278. Further attempts to construct speaking devices are mentioned by Hankins and Silverman, e.g. by Pope Sylvester III, Robert Hooke, and, in the late 18th century, the abbé Mical and Erasmus Darwin.

11 As Ungeheuer, "Über die Akustik des Vokalschalls im 18. Jahrhundert. Der Euler-Lambert-Briefwechsel und Kratzenstein," pp. 157 reports, it was Euler's son who formulated the prize question.

12 Wolfgang v. Kempelen: *Mechanismus der menschliche Sprache nebst der Beschreibung seiner Sprechenden Maschine*, Stuttgart, Bad Cannstatt: Fromman (Holzboog), 1970 [reprint of the edition Wien: Degen, 1791] French and Italian can be produced more easily than German. Also, the sentences should not be too long, as Kempelen admits: "Ganze Redensarten kann ich nur wenige und kurze sagen, weil der Blasebalg nicht groß genug ist, den erforderlichen Wind dazu herzugeben. Z. B. vous etes mon ami". (p. 455f.)

13 Robert Willis, "On vowel sounds, and on reed-organ pipes," *Transactions of the Cambridge Philosophical Society* 3 (1830), pp. 231-268, quote on p. 233.

against a revolving toothed wheel, an alternation of sound qualities was produced that depended on the length of the vibrating portion of the spring. "In effect the sound produced retains the same pitch as long as the wheel revolves uniformly, but puts on in succession all the vowel qualities, as the effective length of the spring is altered, and that with considerable distinctness, when due allowance is made for the harsh and disagreeable quality of the sound itself."[14]

Some thirty years later, Helmholtz would report on this experiment to strengthen his own argument that sound color is independent of a particular sound source. Singling out Willis's experiment, in which the similarity of sound sources was most clearly abandoned, he still remained critical.[15] Even there he saw a simulation of articulation. "Willis's description of the motion of sound for vowels," he commented, "is certainly not a great way from the truth; but it only assigns the mode in which the motion of the air ensues, and not the corresponding reaction which this produces in the ear."[16]

By 1863, when his comprehensive study on hearing *On the Sensations of Tone as a Physiological Basis for the Theory of Music* appeared, Helmholtz had investigated the sounds and functions of musical and acoustical instruments, including the reed instruments. In reed pipes, a stream of air that is regularly interrupted produces the tone. An opening that opens and closes cuts the air stream into parts with the help of a reed. The resulting air "puffs" will be heard as a tone whose pitch depends on the velocity with which the puffs follow each other. This family of instruments comprised some types of organ pipes, and the pipes of the harmonium (i.e., the reed organ), but also the human vocal tract, the "singing voice." In the voice, he considered the vocal cords or the "membranous tongs" to perform the part of the reed.

The sound of the voice, and more specifically, of vowels, depends both on the "membranous tongs," i.e., the vocal cords, which can change the velocity of their movement freely, and on the air chamber, i.e., the mouth cavity, which can change its shape. Both parts of the sound production can vary independently. The voice can sing a melody on the vowel *A* alone, or stay on the same pitch level and pronounce *A*, *I*, and *O*. The two varying parameters of the voice thus had their corollary in the mechanism of articulation. The specificity of the vowel sounds lay, it was assumed, in the relationship between the vocal cords and the air chamber. Helmholtz stated that the pitch range of the vocal cords is, in most cases, lower than the resonance tone of the air chamber. Therefore, the air chamber reinforces, he assumed, one of the partials of the sound produced by the vocal cords.

Connecting these findings to his theory of hearing, Helmholtz wanted to find out how the parameters of the voice related to his concept of the compound tone. The correlation of the vocal cords and mouth cavity to pitch and tone color left open whether and how they related to the functions of the ear. The question was whether a mechanism in the ear that would be able to detect the differences among the vowels was conceivable. The resonance experiments had shown that a device like the open piano was able to echo these differences. Still, two aspects had to be clarified. Firstly, the resonance experiment with the piano was a good demonstration but offered little help in measuring the data. So the actual modification of the compound tones that would be heard as

14 Willis, "On vowel sounds," p. 249f.

15 Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, New York: Dover, 1954 (reprint of the edition London 1885, translated by Alexander Ellis after the 4th German edition of 1877), pp. 118.

16 Helmholtz, *On the Sensations of Tone*, p. 118.

a particular vowel would have to be investigated with other means. Secondly, the formal description of a periodic wave that was at Helmholtz's disposal would be determined by more than just the parameter of frequency. The analyses that could be done with resonance allowed frequencies to be discriminated quite precisely. Also, it could be shown that amplitude mattered although there was no way to measure it exactly. So, again, he had to find out how amplitude related to the discrimination of vowels. A third parameter had not been taken into account in the resonance experiments at all, namely the phase of the waves, i.e., the beginning of the vibrating movement in time. The visual representation of a periodic wave would change with these three parameters, yet it was unknown how this related to hearing.

The resonance theory claimed that the inner ear functions as a Fourier analyzer, as Helmholtz explained in a lecture held in 1857, "The material ear does precisely what a mathematician does by means of Fourier's theorem, and what the pianoforte accomplishes when a compound mass of tones is presented to it. It analyses waveforms which do not have the form of simple undulations [...] into a sum of simple tones, and feels the tone pertinent to each simple wave separately, whether the wave originated in the compound form from a source or became compounded on the way."[17] In order to verify this claim, Helmholtz had an apparatus constructed that enabled him to synthesize sounds from simple tones. In this way he could observe the creation of compound sounds that did not originate in a single sound source, but had one source for each simple tone. Also he could modify the amplitude and phase of the simple tones his apparatus produced. The physical tones were generated by tuning forks filtered with resonators. The tuning forks were set into motion by an electromagnet; their strength could be modified by changing the distance between fork and resonator, and their phase was altered by partly closing the resonator. The frequency of the forks, however, could not be altered. Changing the parameter of frequency would have meant altering the frequency of not just one but three devices per simple tone – the sound generating fork, the resonator, and the fork that served as an interruptor for the electromagnet. It was therefore more convenient to work with only one series of simple tones and to compare the variations that could be achieved with these.

In his famous *experimentum crucis* Helmholtz showed that the ability to discriminate vowel sounds could apply to synthesized sounds. Adjusting his set of forks and resonators to different amplitudes, he distinguished between different vowels. Changing the phase, however, did not affect the discrimination of these compounds. That phase was thus excluded was in line with the expectations of the resonance theory. The concept of resonance, which is based on a minimum amount of time necessary for the detection of identical frequencies, would not easily fit with the temporal discrimination necessary to distinguish between the minute temporal intervals between phases. The theory of hearing thus only had to explain how changes in amplitude and frequency could be sensed. This was no contradiction to the resonance theory, as the resonating particles in the inner ear could be assumed to react at different intensities in an appropriate way to convey the amplitude of the incoming sounds.

The ear could now be said to discriminate compounds of simple tones that differed in frequency and amplitude. Using a separate sound source for each component of the compound

17 Hermann von Helmholtz, "On the Physiological Causes of Harmony in Music" (1857), in: *Helmholtz on Perception: Its Physiology and Development*, ed. by Richard M. Warren and Roslyn P. Warren, New York, London, Sidney: John Wiley & Sons, 1968, 27-58, p. 46, translation changed.

vowel sounds, i.e., for each "physical tone," the "apparatus for the artificial construction of vowels" broke down the two properties of the voice, namely the variability of pitch and sound color, into two parameters of frequency and amplitude that characterized the sound of each physical tone component. Although the experiment synthesized vowel sounds, it was not modeled on articulation, but on hearing or, more precisely, on the assumed functions of the inner ear. The synthesized sound related to the sound of the vowels in a peculiar way: according to the resonance theory, the observed synthesis corresponded to the analysis that occurred in the ear.[18] The functions of the ear were objectified in the sense of being put in a position outside of the observer and his senses.

3. The sound object in the experimental set-up

The three stages of research on vowel sounds discussed above had set themselves different tasks: speaking machines around 1780 tried to imitate articulation, acoustic experiments around 1830 investigated the movements of sound in the air, and experiments in the physiology of hearing around 1850 sought to corroborate a theory on the functions of the inner ear. What was common to them is that they all created artificial vowel sounds. These sounds have certain epistemic functions in common that allow the major differences in their contexts to be observed.

Firstly, the artificial creation of vowels necessarily reified some function of the human body. Vowels were articulated and heard. The three examples show how the two functions of articulation and hearing were separated and studied individually. Secondly, the fact that a sound was created allowed the researchers to observe more than was originally sought. To put it differently, the sounds obtained an existence that was independent of the purposes for which they were created. This becomes most obvious when later researchers found answers to their own questions in the observations of their forerunners. Significantly, the new understandings depended on the actual production of sound. The fact that the vowels, or rather their reproductions, actually did sound in the investigation materialized them in a way that was not entirely predictable. This opened up the possibility of observing something that did not match the questions that were intended to be answered. Thirdly, all these sounds were capable of being interpreted in different ways. The double role of the vowels was the most conspicuous example for this, as the sounds of the voice are used both in the system of music and speech. If subject to experimentation, sung vowels could be regarded as either sharing properties with musical instruments or with other language sounds. This was, however, the reverse side of the second property: as soon as there is sound that is produced under well-defined conditions, it can be reproduced and its alleged purpose questioned.

The separation of articulation and hearing marks the line that separates 18th-century research on the capabilities of the senses from 19th-century sense physiology. Referring back to the distinction between inside and outside, which has been discussed by Jonathan Crary using the example of the *camera obscura*, one could look for such a distinction in research on hearing. However, as the example of vowel synthesis demonstrates, the question must be put in the

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[18] Cf. also Timothy Lenoir, "Helmholtz and the Materialities of Communication," *Osiris* 9 (1994) [*Instruments and the Production of Scientific Knowledge*, eds. Thomas P. Hankins and Albert van Helden], 184-207, who even goes so far as to describe the action in the inner ear as synthesis itself.

appropriate way. The speaking machines show that production and perception were not separated in the 18th-century devices. Even the *camera obscura* is primarily a device to produce images. In the case of vision, production and perception are less clearly distinct, and the production of vision is therefore more easily confounded with the production of visible images, as Crary critically remarks.[19] Also, the imitation of speech was still connected to the idea of mental illusion. From there no straightforward connection could be made to an objectiveness of the outer world.

Only in the 19th century did researchers such as Willis discover the sound of speech as an object worthy of investigation in its own right. In contrast to earlier acousticians, Willis understood the role of differentiation in the vowel sounds. Rather than investigating the individual vowels, he investigated the entire system of vowels. His article on vowel sounds and reed pipes sought a systematic variation in sound color. Systematically varying two parameters – the length of a reed and a pipe – had shown that a given number of sound colors tended to be recognized as the vowels of human language.

In Helmholtz's experiments, the vowels were not so much the object of study as a component in objectifying the functions of hearing. As the experimental set-ups reified the assumed functions of the inner ear, the vowels took on the role of objects of aural perception. Departing from here, the sound object could be defined as the object of experimental research in hearing that reifies aural perception and therefore requires the reification of its objects. Through reification, the sounds that resulted under these conditions obtained a specific ambiguity. Their quality of objectiveness resided in the fact that they could be heard not only in the way which was given by the reification of hearing, but in unpredictable ways.

Referring to Hans-Jörg Rheinberger's notion of the experimental system and the differentiation between the "technical object" and the "epistemic thing," one can sum up the role of vowel sounds as sound objects.[20] The double nature of the object of investigation in research on sense perception makes it difficult to identify an epistemic thing in this area of research. The "objects of knowledge" that also can be called epistemic things are characterized by a specific vagueness. The epistemic thing is something unknown, as the researcher does not know it yet. To question the nature of the epistemic thing is therefore a historical question, as Rheinberger points out. One must look at those conditions of the research which, from the point of view of the researcher, are stable. These conditions can be called the technical objects.

Research in sense perception, however, consciously worked with two unknowns. The array of vague and stable elements is therefore distributed on two levels. In Helmholtz's physiology of hearing, the sensations of tone were declared to be the object of the investigation. Despite the hypothetical status of the sensations of tone, this research brought forth a great number of insights and methodological innovations that outlasted the resonance theory of hearing, such as the simple tone, additive sound synthesis and Fourier-analysis. These results can be said to have become technical objects or black boxes in the sense of Bruno Latour, i.e., unquestioned devices of routine.[21]

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19 Cf. Crary, *Techniques of the Observer*, p. 17ff. (see above).

20 Cf. Hans-Jörg Rheinberger, *Toward a History of Epistemic Things. Synthesizing Proteins in the Test Tube*, Stanford, Calif.: Stanford Univ. Press, 1997.

21 Cf. Bruno Latour, *Science in action*, Cambridge, MA and London: Harvard UP, 1987, p. 24.

The role that the sound object assumes is twofold, as the vowel sounds show. Vowels are used in language, where their function need not be questioned. As soon as they enter the experiment, their stability is additionally granted by the controlled conditions of the experimental set-up. In Helmholtz's experimental physiology, the set-up was both a reification of the functions of hearing, and the actual object of investigation and, as such, to some extent unknown.

A Cosmos for Pianoforte d'Amore: Some Remarks on "Miniature *Estrose*" *by Marco Stroppa*

Florian Hoelscher

Even after many years of familiarity with Marco Stroppa's "miniature estrose" the moment of my first encounter with them is still very present: at a concert of my teacher, Pierre-Laurent Aimard, on whose initiative the pieces were written, the thrill of this gigantic cosmos struck me like a thunderbolt. The piano sounded like no piano that I had ever heard before and the richness of the pieces had such an overwhelming effect on me that I have never since ceased to work on these "miniatures". Finally, in February 2002, i was privileged to perform the world premiere of the complete work at the WDR in Cologne.

In the meantime I had sufficient opportunity to reflect on the secrets of this peculiar soundworld, filled with overtones, and on the inner life of the piano sound. Single keys and even whole harmonies are depressed silently, raising the dampers for these notes, so that a part of the sound actually played – or the overtone spectra of the silent notes – rings on as a shadow, like a constant companion.

It is in the nature of these resonances that they have neither a definite beginning, as they are not played but instead crystallise out of those notes actually struck, nor a definite end, as they are undamped. As such they stand in contrast to the actual sound of the piano, which is marked by clarity of attack and of damping and thereby possesses a clearly defined envelope. A great charm of composition with overtone resonances is in this opposition of "real" and "perceived" sounds.

In the present cycle of piano pieces Stroppa divides the piano sound into layers of clearly defined played notes on the one hand and unplayed, resonating notes on the other hand, creating a "new" instrument which he calls "pianoforte d'amore". He uses resonance not only as shadows of "real" notes and not only as enriched silence. Using various qualities of keystroke which tend above all to minimise the attack at the onset of a struck note, using quasi homogenous tremoli and trills he invents diverse ways of mediating between the state of acoustic resonance and the clarity of "real" notes and, repeatedly, of leading from one to the other.

Stroppa uses the damper pedal largely as a filter through which harmonics and resonances are slowly released from the struck notes – the sound undergoes a metamorphosis without anything new being added to it, as if sounds are being filtered, balanced and modified at a mixing desk. This reveals an entirely new dimension of the instrument: the possibility to develop continuously the sound after it is struck, that is of sostenuto and legato. A centuries-old dream of pianists is thereby at least partially fulfilled and the instrument's inherent possibilities are thus enriched more than by a whole catalogue of new techniques and preparations.

Florian Hoelscher
translation Andrew Digby

The "Muscle Telephone": The Undiscovered Start of Audification in the 1870s

Florian Dombois

Abstract:

In 1992 the first International Conference of Auditory Display (ICAD) was organized; it defined a new area of research – sonification. The use not of graphs but of sound for the interpretation of data has boomed since then, and the yearly ICAD conference brings together many researchers from all over the world. Different methods have been developed such as 'audification' or 'parameter mapping,' and the community has been fighting successfully for the use and acceptance of this equivalent to visualization. The computer as a medium for easily transforming data into sounds and the Internet as a medium for distributing the acoustic results are playing an important role. It is not widely known that the history of sonification dates back not just a few decades to single publications in the 1960s but much earlier. In 1876 the telephone and the loudspeaker were invented, and theoretically, this is the moment when audification first became possible. Indeed, just at that time a series of papers was published describing the use of these new tools for listening to electric signals from nerves and muscles. Researchers from Russia, France, Switzerland and Germany connected the cells of animals and also human beings to a loudspeaker, and instead of watching a galvanometer, they listened to the electric oscillations. One major advantage was the high gain of the telephone as an instrument, as well as the ability to classify the frequency characteristics of the signal during different muscle contractions or nerve activities. Julius Bernstein even went so far as to connect a microphone to a muscle with a speaker at its other end, which changed the tissue into a transducer. He called this a *Muskeltelephon* (1881) and investigated therein the transmitting qualities of cells.

1. Introduction

Let me start with a captatio benevolentiae: In this paper I will not be able to give a full historical examination of the topic. My point of view is more that of somebody who works with sonification in his artistic research and who is interested in the historical development of the technique. Since sonification is not widely known yet, I should also spend some words on this acoustic counterpart of scientific visualization. The research community defines it thus: "Sonification is the use of non-speech audio to convey information."[1] That is to say, instead of portraying numbers on graphs, in sonification, data are related to sounds. This can be done in various ways, which I would like to explain with an analogy to music:

Music is ephemeral, this is evident. It has a form that is expressed over time but cannot be touched. Music is difficult to archive and three main techniques have been used to challenge its fugaciousness: (i) the *score* as a code of instruction for the use of instruments or other sound

[1] Gregory Kramer et al., *Sonification Report: Status of the Field and Research Agenda*, 1997, http://www.icad.org/websiteV2.0/References/nsf.html (accessed 10 December 2006). The international community of sonification researchers comes together yearly at the International Conference of Auditory Display (www.icad.org). This conference was founded in 1992, which can also be assumed to be the beginning of systematic and professional research in the field.

generators for later re-enactment; (ii) the *recording* as the acoustic complement to photography, which registers the sound wave at a specific point of listening, and (iii) the *instruments* themselves, which do not allow a clear reproduction of the original melody, but at least give an impression of the acoustic quality of music of former times. All three techniques have their advantages and disadvantages since they cannot exactly repeat the original, but they all allow a specific perspective on music and disclose aspects that perhaps otherwise would not be heard. The first approach, for example, stresses more the single tone and its symbolic value, the second traces the exact physical wave in a more analogue manner and the third defines the musical material. In sonification one can find these three perspectives too: (i) the technique of *parameter mapping*, (ii) the technique of *audification* and (iii) the technique of *model-based sonification*. In this paper I want to concentrate on the second.

In his book *Auditory Display*, Gregory Kramer writes: "The direct playback of data samples I refer to as 'audification'."[2] And as an update of this definition we find: "Audification is the direct translation of a data waveform into sound."[3] To give an example, let us assume that we have a series of data that might not even belong to the sound domain. A common display would be a Cartesian graph. If the visualized data have a wavelike shape, e.g. an EEG registration, audification would mean attributing the abscissa to time and the ordinate to air pressure and transferring the results to a speaker, where the data would then become audible. The hope behind this media shift is the same as for all sonification techniques, that another mode of depiction will disclose other aspects of the data or allow other aspects to emerge that might not have been discovered before. It is a direct alternative approach to visualization, since all abstract data series can be either visualized or audified. So one might define audification as a technique for making sense of data by interpreting any kind of one-dimensional signal (or of a two-dimensional signal-like dataset) as amplitude over time and playing it back on a loudspeaker. And since all data end up in a speaker, audification is essentially a continuous, non-digital interpretation of datasets.

2. The first audifications

If we change our point of view now towards the past, it is obvious that audification became technically possible not earlier than 1876 when Bell invented the telephone including the loudspeaker. But interestingly, the introductory books like Kramer's *Auditory Display* start their history of sonification – if not with Pythagoras or Kepler – much later, in the 1910s, when the Optophone, an interface for the blind, and sonar became available. Due to some lucky circumstances I can present here a series of seven older papers.[4] Already in 1878, not much after the invention of the telephone and its release on the market, researchers in the area of medicine started to use it as a new tool. In the following I want to go through these papers briefly and in chronological order.

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2 Gregory Kramer (ed.), *Auditory Display: Sonification, Audification, and Auditory Interfaces*, Reading, MA: Addison-Wesley, 1994, p. xxvii.

3 Bruce N. Walker and Gregory Kramer, "Ecological Psychoacoustics and Auditory Display," in: *Ecological Psychoacoustics*, edited by John G. Neuhoff, New York: Academic Press, 2004, pp. 150-175, here p. 152.

4 I would like to thank Julia Kursell, Thomas Koenig and Gerold Baier, who all contributed greatly to the process of finding the papers presented here from the 1870s.

Ludimar Hermann: Ueber electrophysiologische Verwendung des Telephons[5]

The first paper was written by Ludimar Hermann, a doctor from Zurich, and handed in on the 3rd of February 1878. It is a quite comprehensive paper of six pages with a lot of ideas. He used audification – and I use this term here even though it had not been invented in those days – for investigating the electric currents in muscles. Here he especially focused on the different frequencies and described the audible sounds with phrases like "*ein schwirrendes Geräusch*" (p. 505).

Arsène d'Arsonval: Téléphone employé comme galvanoscope[6]

In a two-page paper probably delivered on the 1st of April 1878, Arsène d'Arsonval, a French researcher from Paris, proposed the telephone as a measuring device for small electric currents. In those days, of course, the frog leg was a common indicator for electricity, which d'Arsonval exchanged for the telephone/loudspeaker.

Arthur Hartmann: Ueber eine neue Methode der Hörprüfung mit Hülfe electrischer Ströme[7]

In a small note published in July 1878, Arthur Hartmann proposed using the telephone not only as a new device for listening tests but also as a tool for tracking small electrical currents.

Eduard Thorner: Beitrag zum Nachweis schwacher Inductionsströme[8]

Another short note, dating from not much later than the 17th of August 1878 was published by Eduard Thorner, a doctor from Berlin. He also proposed using the telephone as an alternative to an electric current test with the tongue. He reported on sensitivity tests, where he could prove small currents in the telephone were still audible although they were not detectable with the tongue anymore.

Johannes Tarchanow: Das Telephon als Anzeiger der Nerven- und Muskelströme beim Menschen und den Thieren[9]

The fifth paper in 1878 was written by a researcher from St. Petersburg, Johannes (Ivan) Tarchanow, and was published on the 28th of October. This is the first one that gives reference to its predecessors, citing d'Arsonval, Hartmann and Thorner. Even though it is only a short paper, we find here a report about a number of experiments: Tarchanow described the sounds of

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5 Ludimar Hermann, "Ueber electrophysiologische Verwendung des Telephons," *Archiv für die gesamte Physiologie des Menschen und der Tiere* 16 (1878), pp. 504-509.

6 Arsène d' Arsonval, "Téléphone employé comme galvanoscope," *Comptes rendus hebdomadaires des séances de l'Académie des sciences* 86 (1878), pp. 832-833.

7 Arthur Hartmann, "Ueber eine neue Methode der Hörprüfung mit Hülfe electrischer Ströme," *Monatsschrift für Ohrenheilkunde und Laryngo-Rhinologie* 7 (1878), pp. 91-92.

8 Eduard Thorner, "Beitrag zum Nachweis schwacher Inductionsströme," *Centralblatt für die medicinischen Wissenschaften* 33 (1878), p. 597.

9 Johannes Tarchanow, "Das Telephon als Anzeiger der Nerven- und Muskelströme beim Menschen und den Thieren," *St. Petersburger medicinische Wochenschrift* 3 (1878), pp. 353-354.

different muscles (not only frog muscles but also human muscles); he proved a clear audibility of muscle contractions; and he improved his experimental setting by introducing a second telephone for comparative listening or for intensifying the listening experience. The last point is of special interest, since the question of the proper audio display is a major issue in sonification today.

Johannes Tarchanow: Das Telephon im Gebiete der thierischen Electricität[10]

Five months later in 1879, Tarchanow came back to his topic with a lot of details. For instance he described the advantages of Siemens telephones versus the first Bell apparatus. He developed a pipe that brought the sound of the membrane better into the human ear to extend the listening ability. He applied the method not only to muscle but also to nerve cells. And he developed an apparatus for multiplying a constant frequency with a measured signal.

Julius Bernstein: Telephonische Wahrnehmung der Schwankungen des Muskelstromes bei der Contraction[11]

On the 28th of May 1881, J. Bernstein spoke in Halle about his experiments (done together with C. Schönlein) using audification to investigate muscle contractions. He related his work to Tarchanow, Hermann, and d'Arsonval and focused mainly on the question of how many contractions per second a muscle cell can execute. Describing "ein deutliches Knattern" (p. 19), he induced up to 700-Hz signals in the muscle, which would still allow him to observe a reaction. Interestingly he described this experiment in musical terminology: *e'* and *e"* frequencies and then later pitching up to *dis"* and *f"* (p. 23).
The last chapter is worth reading (and it also gives my paper its title):

> Wir haben zum Schlusse uns auch eines zweiten Telephones als Reizapparat bedient, indem wir dasselbe an die Stelle der Inductionsvorrichtungen setzten, da es interessant war, zu erproben ob die Muskelerregung etwa auch Sprachlaute wiedergeben könnte. Beim Hineinrufen in das Muskeltelephon hatten wir sogar schon Zuckungen in dem Muskel auftreten sehen und erhielten daher vom Nerven aus durch das mit ihm verbundene Reiztelephon ganz kräftige Contraktionen. Jeder in dieses hineingesungene Ton war deutlich vom Muskel aus wahrzunehmen, mit der der Stimme charakteristischen Klangfarbe. Auch die hineingesprochenen Vokale hörte man in dem Muskeltelephon, besonders O und U ziemlich deutlich, dagegen waren a, e und i schwer zu unterscheiden, das r wieder ausserordentlich deutlich; die Consonanten gaben nur unbestimmte Geräusche, so dass Worte nicht zu verstehen waren. Letzteres ist schon ein Beweis dafür, dass wir auch hier nicht etwa die erregenden Ströme gehört haben, doch unterliessen wir nicht, den Controlversuch anzustellen. (pp. 26-27)

We see here the change of an acoustic transducement as an index for material qualities.

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10 Johannes Tarchanow, "Das Telephon im Gebiete der thierischen Electricität," *St. Petersburger medicinische Wochenschrift* 4 (1879), pp. 93-95.

11 Julius Bernstein, "Telephonische Wahrnehmung der Schwankungen des Muskelstromes bei der Contraction," *Berichte über die Sitzungen der Naturforschenden Gesellschaft zu Halle* (1881), pp. 18-27.

Nikolai Wedenskii: Die telephonischen Wirkungen des erregten Nerven[12]

The last paper of my presentation is again from a Russian researcher, Nikolai Wedenskii, published on June the 30th in 1883. Wedenskii compared the acoustic quality of muscle and nerve cells and concluded that the only difference he could find was that *Muskeltöne* go down earlier than *Nerventöne* due to the faster exhaustion of muscle cells.

3. OUTLOOK

I want to close my little overview with two remarks. First, I think it should be obvious how fruitful a historical investigation of sonification could be. Probably because the term was created so recently, nobody – as far as I know – in the history of science has invested in an overview yet. But I am convinced, as I have also written in a recent paper,[13] that there is enough material for at least a PhD thesis.

Second, I think it is worthwhile to structure this history of sonification or to check it from a media perspective. In my opinion, the technical possibilities of reproducing sounds were a major influence, if not the driving force, for the development of sonification. As we have seen, the invention of the telephone and the speaker in the 1870s gave rise to sonification as a scientific method. A second era I would see in the follow-up would be the development of magnetic tape (and talkies in cinema). Especially after World War II, audio tape became a common and cheap storage medium for data, and what was more at hand then playing the data on a tape machine? As the third era, I see a major change with the start up of the Internet in the 1990s, when not only the ICAD was community founded, but also the worldwide distribution of sound became possible – a development that hasn't reached its full potential yet.

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12 Nikolai Wedenskii, "Die telephonischen Wirkungen des erregten Nerven," *Centralblatt für die medicinischen Wissenschaften* 31/26 (1883), pp. 465-468.

13 Florian Dombois, "Sonifikation: Ein Plädoyer, dem naturwissenschaftlichen Verfahren eine kulturhistorische Einschätzung zukommen zu lassen," in: Petra Maria Meyer (ed.), *Acoustic Turn*, Paderborn: Wilhelm Fink, 2007, pp. 87-96 (in print).

Silence in the Laboratory: The History of Soundproof Rooms

Henning Schmidgen

Anybody who knows John Cage knows the story. When Cage came to Cambridge at the beginning of the 1950s, he visited an anechoic chamber at Harvard University. He entered the room expecting to experience absolute silence. To his surprise, two sounds became noticeable: a high one and a deep one. Cage asked the engineer who was responsible for the room what the origin of these sounds might be. The answer was: "The high one was your nervous system in operation, the low one was your blood in circulation."[1] Cage drew the conclusion from this that there was no such thing as absolute silence. As he put it: "Something is always happening that makes a sound."[2] It was shortly after this experience that he composed the piece that anybody who knows John Cage also knows: 4′33″. On August 19, 1952, it was premiered by David Tudor in Woodstock, New York.

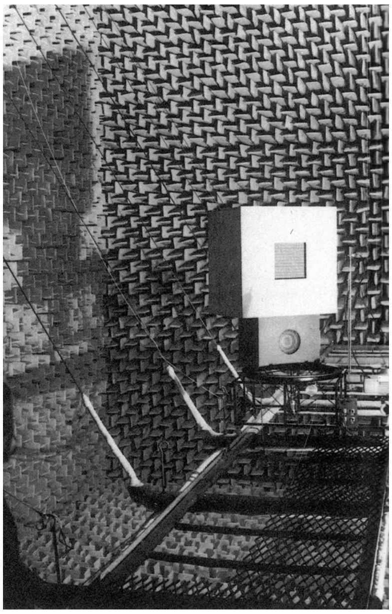

Fig. 1: Interior of the anechoic room at the Cruft Laboratory of Physics, Harvard University, ca. 1950.

1 John Cage, "How to Pass, Kick, Fall and Run," in: idem, *A Year from Monday: New Lectures and Writings*, Hanover, NJ: Wesleyan University Press, 1967, pp. 133-141, quote on p. 134. See also John Cage, "Composition as Process," in: idem, *Silence: Lectures and Writings*, Middletown, CT: Wesleyan University Press, 1961, pp. 18-34, here p. 23, and John Cage and Daniel Charles, "Third Interview," in: *For the Birds: John Cage in conversation with Daniel Charles*, London and Boston: Marion Boyars, 1981, pp. 101-120, here pp. 115-116. – Unless otherwise stated, all translations from German into English are my own (H.S.).

2 John Cage, "45′ minutes for a speaker," in: idem, *Silence*, pp. 146-193, quote on p. 191. See also ibid., p. 152: "Silence, like music, is non-existent. There are always sounds."

While this story is well known, it is still uncertain precisely what room it took place in. At that time Harvard University had two anechoic rooms (or perhaps even three, as Doug Kahn argues). One had been set up in 1943 and belonged to the Cruft Laboratories, a research lab for physics founded in 1913 where, in the early 1940s, the legendary *Mark I* computer began to work. Frederick Vinton Hunt used this anechoic room to test acoustic devices such as microphones and headphones for their usability in war (fig. 1). The other anechoic room was in the Psychoacoustics Laboratory located in Harvard's Memorial Hall. This laboratory had been set up in 1940 as an extension of the research sites for psychology, which had existed at the university since the days of Hugo Münsterberg. Its anechoic room was used by Stanley Smith Stevens to investigate the psychoacoustics of hearing and human communication (fig. 2). Now, which of the rooms had Cage been in? The fact that he received as an answer to his question that the sounds he heard were caused by the circulation of his blood and the working of his nervous system suggests that he had been in the Psychoacoustics Laboratory, but that an engineer answered his question would seem rather to point to the Cruft Laboratories.[3]

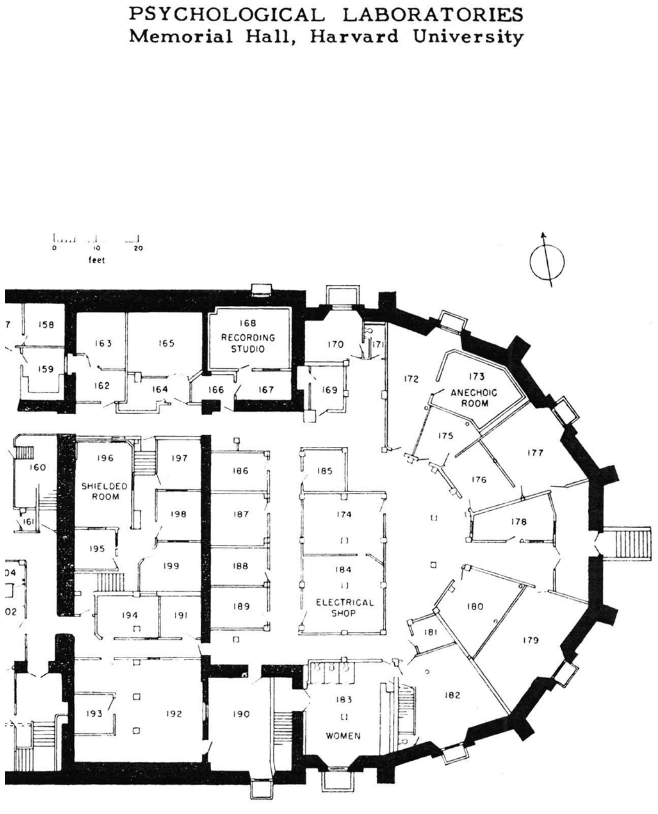

Fig. 2: Plan of the Harvard Psychology Laboratory with anechoic room (1947).

[3] David Revill, The *Roaring Silence: John Cage; A Life*, New York: Arcade Publish., 1992, pp. 162-186. A description of the soundproof room of the Psychoacoustic Laboratory can be found in: Stanley S. Stevens and Edwin G. Boring, "The New Harvard Psychological Laboratories," *The American Psychologist* 2 (1947), pp. 239-243.

The decisive point here, however, is not *where* Cage had his experience of "roaring silence" but *that* it became the foundation of his later work as an experimental composer. In the early 1940s, Cage had at first based himself on a dialectical concept of silence, which he used to penetrate the structures of musical material. At this point sound and silence were mutually exclusive phenomena for Cage, which by their succession determined essentially what music was. Not much later he developed a spatial idea of silence that diverged from his original idea. It was his involvement with the music of Erik Satie that played a critical role here. Silence related now above all to surrounding noises that were heard by certain listeners in concrete situations. It was only after his Harvard experience that Cage came to associate silence with unpredictability and, insofar, with time. After his visit to the anechoic room, the idea emerged that the sounds that filled the silence were associated with each other by the absence of intention. The sounds of silence had in common that they followed no defined direction, determination, or meaning. Humming and buzzing thus became the zero-state of hearing *and* making music, a state in which there was a constant openness with respect to what happened next – which also meant that silence and living time had moved closer to each other. To quote again Cage: "The common denominator is zero, where the heart beats (no one *means* to circulate his blood)."[4]

In recent years the spaces in which art and science are produced and received have come increasingly to occupy the interest of scholars in sociology, history, and cultural studies.[5] Whereas the *camera obscura* and the various optical devices associated with it have been the subject of numerous studies,[6] to date no comparable investigations have been devoted to its acoustical counterpart, the *camera silenta* and similar structures – although their history probably points to equally productive assemblages. My paper draws attention to the peculiarity of these rooms and offers a first contribution to their history. My main argument is that, contrary to what one might expect, the emergence and development of soundproof rooms do not primarily refer to the history of acoustics, radio technology and/or simultaneous translation. Rather, they refer to the history of time, in particular time research as it was carried out, since the 1870s, in physiological and psychological laboratories. The initial motive behind the construction and use of such rooms was to avoid disturbances of test persons involved in reaction time experiments and the resulting measurement errors. Today I would like to bolster this argument by way of a case study centering

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4 John Cage, "Erik Satie," in: idem, *Silence*, pp. 76-82, quote on p. 80. See also the article by Eric de Visscher, "'So etwas wie Stille gibt es nicht ...:' John Cages Poetik der Stille," *MusikTexte* 40/41 (1991), pp. 48-54; Daniel Charles, "Über die Nullzeit-Poetik von John Cage," idem, *Musketaquid: John Cage, Charles Ives und der Transzendentalismus*, Berlin: Merve Verlag, 1994, pp. 95-118.

5 See, for example, Brian O'Doherty, *Inside the White Cube: The Ideology of the Gallery Space* (Santa Monica: Lapis Press, 1986); Douglas Crimp, *On the Museum's Ruins*, Cambridge, MA: MIT Press, 1993; Caroline A. Jones, *Machine in the Studio: Constructing the Postwar American Artist*, Chicago: University of Chicago Press, 1996; Hans-Jörg Rheinberger, Michael Hagner, and Bettina Wahrig-Schmidt (eds.), *Räume des Wissens: Repräsentation, Codierung, Spur*, Berlin: Akademie-Verlag, 1997; Peter Galison and Emily Thompson (eds.), *The Architecture of Science*, Cambridge, MA: MIT Press, 1999; Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933*, Cambridge, MA: MIT Press, 2002.

6 See, among others, Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century*, Chicago: Chicago University Press, 1983; Jonathan Crary, *Techniques of the Observer: On Vision and modernity in the Nineteenth Century*, Cambridge, MA: MIT Press, 1990; Friedrich Kittler, *Optische Medien: Berliner Vorlesung 1999*, Berlin: Merve Verlag, 2002.

on the debate triggered by the publication of two Swedish scholars in Wilhelm Wundt's Leipzig lab and other places in the late 1880s.[7]

Soundproof rooms are laboratory fractals. Similar to respiration rooms and bubble chambers, they re-embody, if one may say so, the architectonic means that modern research sites use to separate themselves off from everyday environments, only to connect up with them by other means: with the help of circuits, pipes, and other infrastructures, but also by means of texts and images.[8] Historiographically, the emergence of soundproof rooms seems to connect itself rather directly with the history of discipline and punishment. It is true that since the early 19th century, there was an almost constant flow of projects aiming at subjecting psychiatric patients and prisoners to kinds of isolation as complete as possible, in order to "improve," "cure," or "protect" patients and prisoners against themselves and others (as the historical actors put it). One example is the book written by the Weimar gynecologist, politician, and publisher Ludwig Friedrich Froriep in 1846, "On the isolation of senses as the basis for a new system of isolation of detainees."[9] In *Discipline and Punish*, Michel Foucault described such projects under the heading of "absolute isolation,"[10] and by the same token pointed to the difference between the corresponding power practices and the process of experimentalization that I would like to focus on here. The architectural structures that I am interested in are not aiming at some complete separation and/or sensory deprivation. They are focusing on one sense modality, i.e., hearing; in particular, their purpose is to render the time of reaction to specific stimuli more appropriate, more precise. This may also explain why the rooms in question were first created in order to cope with noises inside, not outside of physiological and psychological laboratories.

It was two Swedish physiologists, Robert Tigerstedt and Jacob Bergqvist, who initiated the development that would result ten years later in setting up the first soundproof rooms in physiological and psychological laboratories. In 1883 Tigerstedt and Bergqvist published their paper "On the Duration of Apperception in Compound Visual Representations." In this paper they expressed considerable doubts as to the times for conscious perceptions that had been measured in the Institute for Experimental Psychology in Leipzig. The two Swedish researchers found the apperception times that had been obtained by the Wundt student Max Friedrich to be clearly too long. They asked the rhetorical question: "How would it be [...] possible to read or write at all if the perception of every letter and every digit were to take several tenths of a second?"[11] This

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7 This paper develops an argument first made in my paper "Camera silenta: Organlosigkeit in Zeitexperimenten um 1900," in: Bernhard J. Dotzler and Sigrid Weigel (eds.), *"fülle der combination:"Literaturforschung und Wissenschaftsgeschichte*, Munich: Fink, 2005, pp. 51-74.

8 On the bubble chamber, see Peter L. Galison, *Image and Logic: A Material Culture of Microphysics*, Chicago, 1997, chap. 5, and Andy Pickering, *The Mangle of Practice: Time, Agency, and Science*, Chicago 1995, chap. 2. On respiration rooms, see Frederic L. Holmes, "The Formation of the Munich School of Metabolism," in: *The Investigative Enterprise: Experimental Physiology in Nineteenth-Century Medicine*, ed. by William Coleman and Frederic L. Holmes, Berkeley and Los Angeles, 1988, pp. 179-210. More generally, see Hans-Jörg Rheinberger, "Wissenschaft zwischen Öffentlichkeit und Labor", in: *Jahrbuch 2000 des Collegium Helveticum der ETH Zürich*, Zürich: vdf, 2001, pp. 159-175.

9 Ludwig Friedrich von Froriep, *Ueber die Isolirung der Sinne als Basis eines neuen Systems der Isolirung der Strafgefangenen*, Weimar: Landes-Industrie-Comptoir, 1846. On Froriep, see also the material in: Olaf Arndt and Rob Moonen, *Camera silens: Ein Projekt von Moonen & Arndt; Parochial-Kirche, 3. bis 24. November 1995*, 2nd expanded and revised ed. Hamburg: Edition Nautilus, 1995.

10 Michel Foucault, *Discipline and Punish: The Birth of the Prison*, New York: Vintage Books, 1995, pp. 238-239.

cultural argument was the point of departure for the two Stockholm scientists for a detailed criticism of the experimental practice that had provided the foundation of Friedrich's publication in the first volume of Wundt's *Philosophische Studien*. Friedrich not only neglected the physiological time that the human eye needed to adapt to sudden bright light stimuli; the very set-up of his experiment interfered with the times he measured. The two scientists referred above all to the fact that during the experiments carried out by Friedrich the experimental subject and the experimenter were in the same room, in which, in addition, the stimulation device and the measuring instruments were also located:

> This means that the reacting subject necessarily was disturbed by the noise of the apparatus used during the investigation – that is, by the rattling of the Hipp chronoscope and the noise of the contact breakers in the induction devices, of which at least the latter is quite loud. Further, the presence of several people in the experimental room, the continual changing of the object, etc., must have had an influence on the mind of the reacting subject.[12]

In other words, the closer the measuring instruments were placed to the experimental subject, the longer the time that was to be measured became. The strategy that the two physiologists suggested for getting around this kind of uncertainty relation was correspondingly simple: The subject being experimented upon was to be separated spatially from both the experimenter and the measuring equipment, but was to be reconnected with both by technical means (fig. 3). Tigerstedt and Bergqvist profited in this from the fact that their device for measuring time – similar to the chronoscope used by Friedrich – used electromagnetism. The "reacting subject" and the "recording subject" could be placed in different rooms, which were connected by wires. Thus, the experimental subject was kept "completely free of disrupting influences."[13] The results obtained in this manner differed significantly from those obtained in Leipzig. With precision to three decimal places, the two physiologists measured apperception times between 0.014 and 0.035 seconds, whereas Friedrich had obtained values between 0.290 and 1.595 seconds. Their general conclusion was "that the true apperception time for a compound representation is so short that it can at most be a few hundredths of a second."[14]

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11 Robert Tigerstedt and Jakob Bergqvist, "Zur Kenntnis der Apperceptionsdauer zusammengesetzter Gesichtsvorstellungen," *Zeitschrift für Biologie* 19/N.F. 1 (1883), pp. 5-44, quote on p. 18.
12 Ibid., p. 17.
13 Ibid., p. 20.
14 Ibid., p. 42.

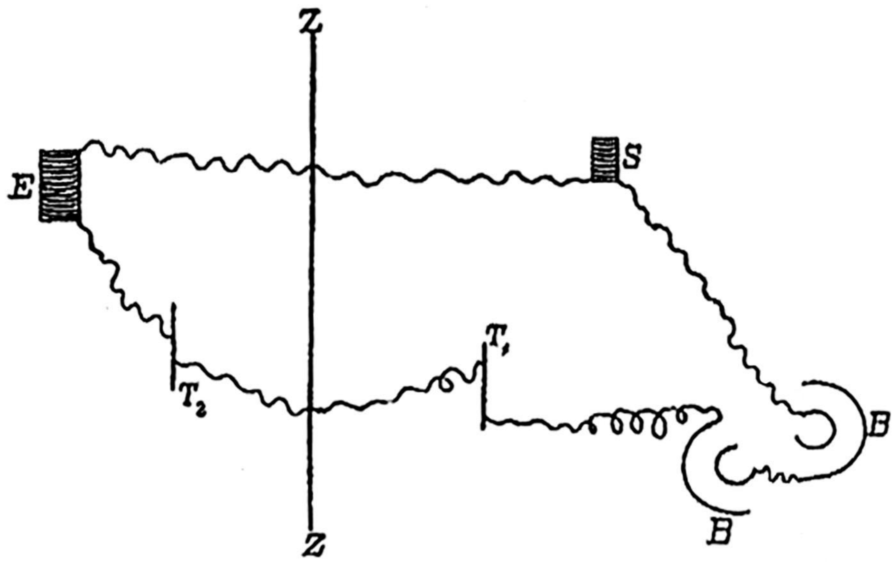

Fig. 3: Schematic drawing of the experimental setup used by Tigerstedt and Bergqvist. The experimental subject is to be imagined on the left, the experimenter on the right. E refers to the electromagnet inside the box for stimuli presentation. S stands for the electric signal by means of which time is recorded. T1 and T2 are the switches handled by experimental subject and experimenter.

The reaction from Leipzig was not long in coming. In 1888 Ludwig Lange published his paper on "New Experiments on the Process of Simple Reactions" in the *Philosophische Studien*. Lange attempted to sidestep the problem of physiological adaptation to time by shifting – in contrast with both Friedrich *and* Tigerstedt and Bergqvist – to acoustical stimuli. Since the early 1860s, when Adolphe Hirsch conducted his chronoscopic investigations at the observatory in Neuchâtel, the ear was apparently considered as being largely unproblematic in this regard (as opposed to the eye). After Tigerstedt and Bergqvist's criticism of Friedrich's experimental set-up, Lange very clearly went to great lengths to remove every conceivable source of disturbance from his investigations. At least for the Leipzig context, his study set the standard for the correct execution of reaction time experiments. Lange's main interest was in making certain that "the noises emitted from the equipment for measuring time would not be disrupting," since these would otherwise "contaminate" the required experimental conditions.[15] Following his Swedish colleagues, he placed the experimental subject and the device producing the stimulus in one room and the experimenter and the measuring equipment in another. The two rooms were connected by electric lines. Further, the experimental subject was given the strict instructions to "avoid all distracting thoughts" in order not to cause any unnecessary "deviations from the normal" in the reaction times.[16]

15 Ludwig Lange, "Neue Experimente über den Vorgang der einfachen Reaction auf Sinneseindrücke," *Philosophische Studien* 4 (1888), pp. 479-510, quote on p. 481.

16 Ibid., p. 485.

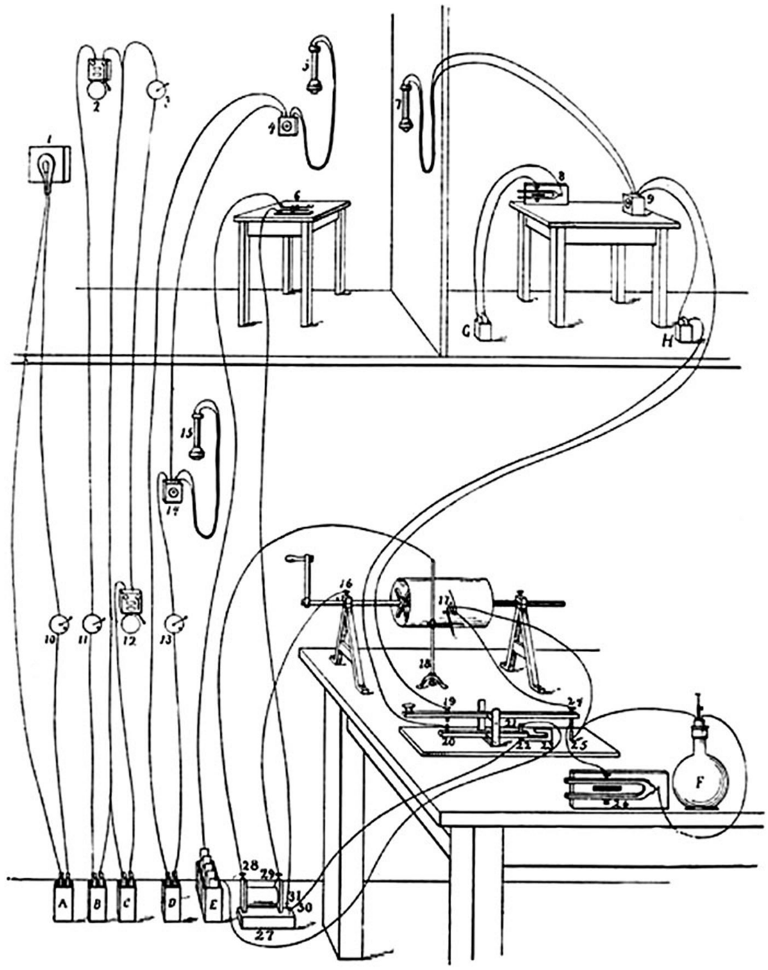

Fig. 4: Drawing of the isolated room (top left) and associated laboratory space in the Psychological Laboratory at Yale University (1895).

Following Lange another Wundt student drew attention to the "surrounding errors" that endangered precise work in psychological laboratories. In his lecture at the second annual meeting of the American Psychological Association in 1893, Edward W. Scripture claimed that "distracting noises [are] probably the worst source of errors" in psychological time experiments. Like Tigerstedt, Bergqvist, and Lange, Scripture was convinced that spatial separation of the experimental subject from the measuring equipment and the experimenter was a suitable way to overcome such disturbances. For him, who had himself worked in the Leipzig laboratory at the end of the 1880s, it was self-evident that "the experimenter, the recording apparatus, and the stimulating apparatus are in a part of the building distant from the person experimented upon."[17] Scripture even went a step further than his European-based colleagues. In his laboratory at Yale University, he set up an isolation room especially for the experimental subject: "[...] to be rid of all distraction the person experimented upon is put in a queer room, called the 'isolated room,'

[17] Edward W. Scripture, "Accurate Work in Psychology," *American Journal of Psychology* 6 (1893), p. 427-430, quote on p. 429.

whose thick walls and double doors keep out all sound and light. When a person locks himself in, he has no communication with the outside world, except by telephone"[18] – and over a telegraph key that was connected with measurement and recording devices located where the experimenter was (fig. 4). Similar arrangements, which were described as "rooms within a room," sometimes even as "rooms within a room within a room", were used in the following years in laboratories at the universities in Leipzig, Utrecht, Princeton, and Austin, among others (fig. 5). In the 1890s, soundproof rooms were mostly used for reaction time measurements. Their use for research concerning problems of psychoacoustics only started around the turn of the century. This was at least the case of Wundt's Leipzig lab and the Yale laboratory, where Scripture, after some studies concerning reaction times, shifted to the field of experimental phonetics and acoustics.

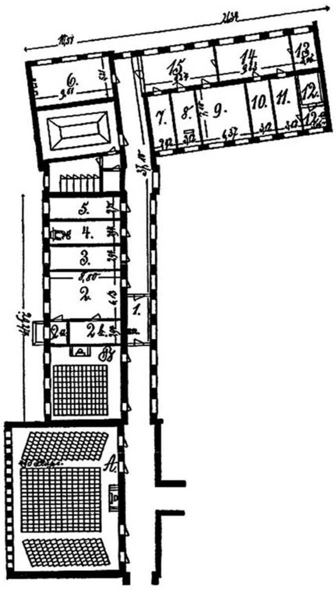

Fig. 5: Soundproof room (12) in the Psychological Laboratory at Leipzig University (1909).

When Cage entered one of the anechoic rooms at Harvard, he did not find the absolute silence he had expected. Similar experiences were made by experimenters and test subjects sojourning in the soundproof rooms of psychological and physiological laboratories. Scripture even went so far as to refer the unexpected noises to temporal phenomena (fig. 6):

> My clothes creak, scrape and rustle with every breath. The muscles of the cheeks and eyelids rumble; if I happen to move my teeth, the noise seems terrific. I hear a loud and terrible roaring in my head; of course, I know it is merely the noise of the blood rushing through the arteries in my ears [...], but I can readily imagine that I possess an antiquated clockwork and that, when I think, I can hear the wheels go 'round.[19]

Remote from every apparent source of noise, there was an encounter with the internal connection between fluid bodily depths and temporality. In the solitude of the isolation room, the

[18] Edward W. Scripture, *Thinking, Feeling, Doing*, New York: Flood and Vincent, Chautauqua-Century Press, 1895, p. 41.
[19] Scripture, *Thinking, Feeling, Doing*, p. 42.

experimental subject was confronted with roarings, rushings, and an inner clock, which apparently could not be escaped. As a consequence, the experimental subject himself emerged as the ultimate disruptive factor of experimental psychology involved with the measurement of time. As Scripture noted: "All the sights and sounds can be shut out, all disturbances of touch can be made small by comfortable chairs, but, alas! we have let in a sad source of disturbance, namely, the person himself!"[20] In other words, the time experiments in the psychological laboratory created a line of flight drawn by the very bearer of the characteristics that were supposed to be investigated.

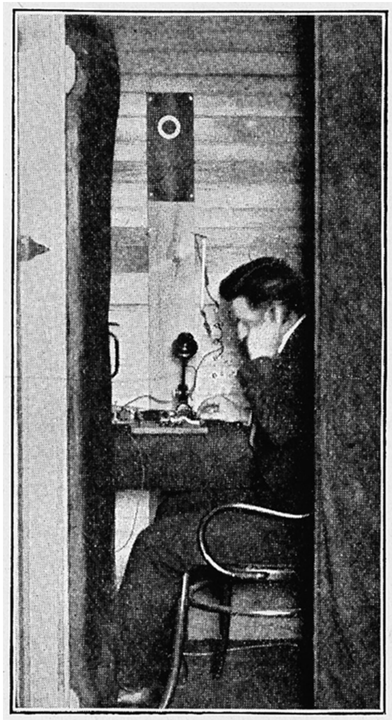

Fig. 6: Subject under experimentation placed in an isolated room, Psychological Laboratory at Yale University (1895).

Similar was the experience made in one of the first soundproof rooms explicitly designed for physiological and psychological research on acoustics. In 1903 the Dutch scholar Hendrik Zwaardemaker devised a camera silenta at the University of Utrecht (fig. 7). In his earlier investigations concerning the physiology of the sense of smell, Zwaardemaker had developed a "zero-method", which he also wanted to use in the area of psychological acoustics. His goal here was not only to isolate the experimental subject from all external distractions; Zwaardemaker also wanted to carry out the individual experiments within this isolation always proceeding from two stimuli, which were so simple that in combination they were perceived as neutral. Thus, the point of departure for his investigations in the soundproof room was a kind of minimal acoustic pair. While he was successful with this method in creating relatively easily a state without smells, achieving a zero degree of noise by this method was not so easy. In 1907 the journal *Science* published a short note on Zwaardemaker's "Noiseless room for Sound Experiments." Ironically,

20 Ibid., p. 41-42.

this note tried to prove the noiseless quality of the room by the very fact that absolute silence was hardly to be experienced:

> The noiselessness of the room is shown by the fact that one hears a subjective buzzing, similar to but of less intensity than the buzzing produced by large doses of quinine. Many normal people also hear their own heart sounds. [...] In the room a few swings of the leg or arm is often sufficient to make the heart sounds quite distinct. Other body noises may also be heard. If a movement of a few inches in extent is made, such as lightly brushing the foot over the carpet or a free movement of the arm, the sound is distinctly audible. So audible are these noises that one must be careful not to move when experiments are in progress.[21]

At this point, it remained rather obscure how psychoacoustic experiments without movements could be performed.

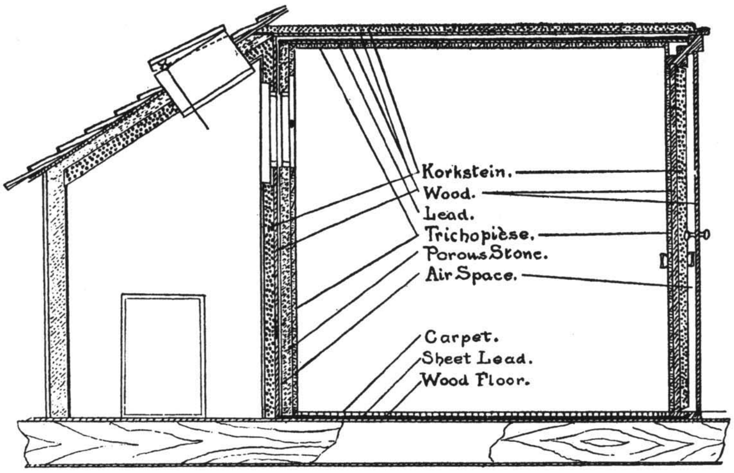

Fig. 7: Soundproof room at the Physiological Institute of Utrecht University (1907).

In his autobiography, Zwaardemaker frankly admitted that deep noises caused by heavy vehicles driving past in front of the laboratory could be heard in his camera silenta. Zwaardemaker attempted to overcome this problem by setting up a further soundproof room inside the already existing room. This room consisted of a movable box with walls made of peat that were covered both from within and from without by heavy layers of horsehair. Only once the experimental subject was inside this camera silentissima was the Dutch physiologist able to achieve satisfying results. Although even then one couldn't talk of absolute silence:

> [...] immediately upon entrance to the room a weak tinnitus in the ears begins. It resembles the wind in the tops of the trees in the woods. Besides this, a high tone appears which is very

21 Shepherd Ivory Franz, "A Noiseless Room for Sound Experiments," *Science*, n.s., 26/677 (1907), pp. 878-881, quote on p. 881.

> near the upper limit of hearing along the tone-scale; also more complex noises occur, which take on, in different degrees, the character of hallucinations, resembling the singing of birds, the crowing of cocks, melodies, etc.[22]

In other words, the isolated inner world connected up with an extended outer world and, as with Cage, it was a form of time that created the connection. Zwaardemaker was not certain whether the sounds in silence were caused by the circulation of the blood or whether they were acoustic aftereffects of noises that he had heard before entering the soundproof room. But regardless of whether it was due to the presence of the body or to bodily *après coup* effects: Within the soundproof double room it was a kind of living time that made itself known, a mobile silence that did not deviate from the zero state being sought but was an exact characterization of it.

In a preliminary way, the further development of soundproof rooms can be summarized as follows. In the 1920s and 1930s, these rooms were part of the standard feature of psycho-physiological laboratories. As already mentioned, they were primarily used in reaction time measurements, in particular in advanced research and when applying acoustical stimuli; secondly, they served for conducting experiments in experimental phonetics and psychoacoustics. However, not only psychological laboratories created and used these structures. In 1932 the Laboratory of Neurophysiology at the School of Medicine at Yale University used a soundproof compartment "for finer acoustic investigations."[23] In 1933 the Amsterdam Institute of Physiology had a "Camera absolute silenta" that was used for research in the fields of physiological acoustics, experimental phonetics, and general muscle physiology, in particular the investigation of heart and muscle sounds. In his description of this chamber, the director of the lab, Gérard van Rijnberk, discussed the problems of protecting the room against the invasion of laboratory animals, in particular mice (fig. 8). He also explained the emergency plan should somebody get locked in inside the chamber. A telephone was installed that connected the chamber with the rest of the institute. More importantly, there was a gripper and a hammer placed in the chamber for opening the door from within. Both these tools were covered with luminescent paint so they could be found easily in the dark.[24]

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22 Hendrik Zwaardemaker, "An Intellectual History of a Physiologist with Psychological Aspirations," in: Carl Murchison (ed.), *A History of Psychology in Autobiography*, Worcester: Clark University Press, 1930, pp. 491-516, quote on p. 506.

23 See Joannes Gregorius Dusser de Barenne, "Yale University: School of Medicine, Laboratory of Neurophysiology," *Methods and Problems of Medical Education* 20 (1932), pp. 25-26.

24 Gérard van Rijnberk, "Die Herstellung eines praktisch vollkommen geräuschlosen Raumes: Camera absolute silenta," in: Emil Abderhalden (ed.), *Handbuch der biologischen Arbeitsmethoden,* Abt. V, *Methoden zum Studium der Funktionen der einzelnen Organe des tierischen Organismus*, Teil 7, Heft 12, Berlin and Vienna: Urban & Schwarzenberg, 1937, pp. 1661-1676.

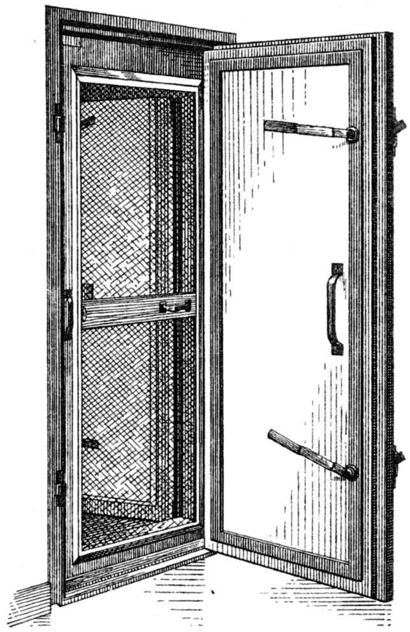

Fig. 654. Eingang der Camera silenta. Man sieht die äußere Tür des äußeren Zimmers mit der Mäusegaze und die innere Tür.

Fig. 8: Entrance door to the camera silenta in the Amsterdam Physiology Laboratory (1930). Note the grid for preventing laboratory mice from entering the room.

Different from what one might expect, the use of soundproof rooms was not limited to human test subjects. With the emergence of behaviorism and Pavlovian reflexology in the 1910s and 1920s, sound isolated rooms were also used for experiments in animal organisms. As Pavlov explained: "The researcher who ventures into recording all environmental influences on the animal organism is in need of quite extraordinary means of research. He must control all exterior influences. This is why he needs, for these investigations, a special type of laboratory where no arbitrary noises occur and no oscillations of light, and no suddenly changing stream of air."[25] In 1913 the physiological department of the Institute of Experimental Medicine in St. Petersburg started to construct a special tower in which, as a first step toward Pavlov's goal, soundproof rooms for dog experiments were devised (fig. 9). The explicit model for these rooms was Zwaardemaker's camera silenta in Utrecht.[26] In the 1930s, the Yale Laboratories for Comparative Psychobiology were proud to have a soundproof room for animal experiments (in this case, mostly primates).[27] And in the 1950s, William Thorpe from the Department of Zoology at University of Cambridge devised a similar room for his investigations concerning the sounds produced by passerine birds, investigations that Deleuze and Guattari were fascinated with.[28]

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[25] Ivan Petrovich Pavlov, quoted after Nikolaj A. Podkopaew, *Die Methodik der Erforschung der bedingten Reflexe*, Munich: Bergmann, 1926, pp. 17-18.

[26] Podkopaew, *Die Methodik der Erforschung der bedingten Reflexe*, p. 23.

[27] Robert M. Yerkes, *Yale Laboratories of Comparative Psychobiology*, Baltimore: Johns Hopkins Press, 1932.

[28] William H. Thorpe and Robert A. Hinde, "An Inexpensive Type of Sound-Proof Room Suitable for Zoological Research," *Journal of Experimental Biology* 33 (1956), pp. 750-755.

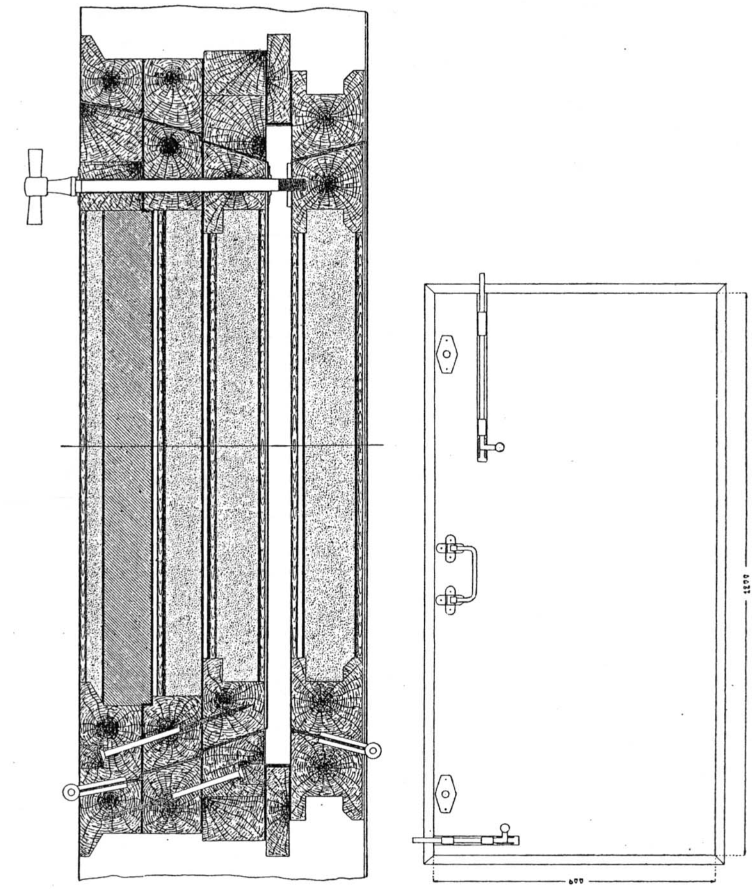

Abb. 13. Innere und äußere Tür der schalldichten Zelle (Horizontalschnitt 1/4 d. nat. Gr.). Reihenfolge der Schichten von oben. Innere Tür: 1. Wachstuch, 2. Wattin, 3. Blei, 4. Fournier, 5. Bast, 6. Ruberoid, 7. Asche, 8. Ruberoid, 9. Filz, 10. Bast, 11. Fournier, 12. Tuch. Äußere Tür: 1. Tuch, 2. Blei, 3. Fournier, 4. Ruberoid, 5. Asche, 6. Bast, 7. Fournier, 8. Ruberoid, 9. Bast, 10. Filz, 11. Ruberoid, 12. Asche, 13. Bast, 14. Ruberoid, 15. Fournier. 16. Bast, 17. Filz, 18. Ruberoid, 19. Kork, 20. Ruberoid, 21. Asche, 22. Bast, 23. Fournier, 24. Wachstuch.

Fig. 9: Cross section showing the door of one of the soundproof rooms in the Physiological Department of the Institute of Experimental Medicine in St. Petersburg (1926).

In the 1950s, however, the principles of constructing and using such rooms had already undergone a significant change. It was no longer only a question of protecting against "exterior" noises (that is, we should recall, above all noises from within the laboratory); the issue had become to create acoustically sophisticated interiors as well. In addition, one should note that in this period the acoustic properties of soundproof structures were no longer a matter of personal experience, but above all part of a technical question answered by means of instruments such as the Dawe sound level meter. In the 1940s already, the soundproof and anechoic rooms in institutions such as the Metropolitan-Vickers Electrical Company, the US National Physics Laboratory, Bell Telephone Laboratories, and Siemens were taken as models, for example in the construction of a soundproof room for physiological and psychological experiments at the catholic university "Sacro Cuore" in

Milan in 1944.[29] And it was a former student of physics and communication engineering at Harvard University, Leo Beranek (today well known for his seminal 1962 book on *Music Acoustics and Architecture*) who suggested providing the two anechoic rooms they were using on Campus during war time with the characteristic wedge-shaped wall elements.[30] The fact that Cage could choose between these two rooms rather nicely embodies the shift in construction contexts and techniques. Beranek also helped to design the interior of the anechoic chamber constructed by the Parmly Foundation for Auditory Research at the Illinois Institute in Chicago in 1947.[31] In the same period, the first handbooks explicitly addressing the problem of constructing soundproof rooms became available.[32]

Conclusion

In one of the anechoic rooms at Harvard, Cage was able to experience his body as a kind of floating and buzzing *fabrica* under the skin. To him, this was the zero degree of music: "no one *means* to circulate his blood." Similarly, Zwaardemaker and Scripture, in their soundproof rooms, did not only encounter movements *in* their bodies, which were removed from every hierarchy of the senses (respiration, circulation, etc.). They also experienced continuations of movements from outside the soundproof rooms: the tops of trees moving in the wind, the singing of birds, melodies... However, this border, the sound intensity 0, which Cage, Zwaardemaker, and Scripture were moving towards, was dealt with in different ways. For the latter two it was a difficult to control *variable* of scientific simultaneity, a disruption of the sought-after form of precise measurement of time; for the first it was a kind of threshold that had to be crossed in order to create a new time regime that would be capable of cultivating new *varieties* of experience. With Thoreau and Meister Eckhart in mind, Cage was the first who conceptualized this kind of *degré zéro* experience: The roaring silence of organlessness is a duration.

In other words, the *camera silenta* is not primarily an acoustic space but a temporal one, a "time-space." And since there is no organ for time, one could say that, in contrast with the *camera obscura,* the silent room is not even focused on a single sense organ. If the ear plays a special role in it, then only as a portal to the dynamic forms that characterize the experience of Scripture, Zwaardemaker, and Cage. The relationship between technology and knowledge that characterizes the *camera silenta* is correspondingly different. The camera obscura, as Jonathan Crary has shown, allows the subject "to guarantee and police the correspondence between exterior world and interior representation and to exclude anything disorderly or unruly."[33] It is possible that the hope of discovering such correspondences motivated the construction of soundproof rooms. But the connection between reflective introspection and self-discipline, which the darkroom seems to have facilitated so easily, encountered clear limits in the camera silenta – not least because the ear

29 Agostino Gemelli, "Criteri fondamentali per la construzione di una camera isolata acuticamente e schermata electricamente per ricerche di fisiologia e di psicologia, e risultati consegutti," *Contributi del laboratorio di psicologia,* 12 (1944), pp. 47-57.

30 Leo Beranek, Electrical Engineer, an oral history conducted by Janet Abbate [22 November 1996], IEEE History Center, Rutgers University, New Brunswick, NJ, USA.

31 Peter J. Mills, "Construction and Design of the Parmly Sound Laboratory and Anechoic Chamber," *The Journal of the Acoustical Society of America* 19/6 (1947), pp. 988-992, here p. 992.

32 See, for example, Edward Gick Richardson, *Acoustics for Architects*, London: Arnold, 1945, pp. 60-79.

33 Crary, *Techniques of the Observer*, p. 43.

stands open and as such is directed not only towards the surrounding space but always also towards inner time. The silent room does not accommodate, therefore, an autonomous, individual self, which has acquired, as Crary puts it, the ability to comprehend intellectually the infinite existence of bodies in space. It accommodates a many-headed, human *and* animal subject that is in the process of dissolution and that, by means of accelerations and decelerations, by movements in place, continually recreates anew the borders between the inside and the outside.

Cats and People in the Psychoacoustics Lab[1]

Jonathan Sterne

This talk is part of a larger project on the history of the mp3 format. One of my central arguments is that there is no such thing as "bare hearing" in scientific or technological contexts. Everything psychoacousticians know about the faculty of hearing is based on the interaction between ears and media. Today, I will consider a particularly gruesome episode in the larger story, a series of experiments where two psychologists wired live cats into a working telephone system. My key points are as follows: 1) cat ears are not an accidental surrogate for human ears, but rather they are tied to the project of "disenchanting" hearing; 2) though the experiment turned out to be faulty, it was a major step toward the fusion of auditory psychology and information theory. This latter project had been underway since 1910, when AT&T consolidated its research department and got involved in "basic" research on human hearing. The ultimate goal was to find a way to incorporate users' life processes into the phone system. That is the context, now onto our story.

One of the major turning points in early psychoacoustics was a series of experiments undertaken by Ernest Glen Wever and Charles W. Bray at Princeton University in 1929. Though their findings were later overturned, their experimental method led to major innovations in psychoacoustic research, and their approach was paradigmatic. Following a procedure developed by physiologists, Wever and Bray removed part of a cat's skull and most of its brain in order to attach an electrode – in the form of a small wire hook – to the animal's right auditory nerve, and a second electrode to another area on the cat's body. Those electrodes were then hooked up to a vacuum tube amplifier by 60 feet of shielded cable located in a soundproof room (separate from the lab that held the cat). After amplification, the signals were sent to a telephone receiver. One researcher made sounds into the cat's ear, while the other listened at the receiver.[2] What they found astonished them. The signals picked up off the auditory nerve came through the telephone receiver as sound. "Speech was transmitted with great fidelity. Simple commands, counting and the like were easily received. Indeed, under good condition the system was employed as a means of communication between operating and sound-proof rooms."[3] Given Helmholtz's still-prevailing theory of hearing and given the prevailing accounts of nerve sensations, the researchers had not expected the nerve itself to transmit pulses that could be transduced back into sound. But it appeared to do just that. Wever and Bray checked for all other possible explanations for the transmission of sound down the wire. They even killed the cat, to make sure that there was no mechanical transmission of the sounds apart from the cat's nerve: "after the death of the animal

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1 For inclusion in the record of the conference. Not for other republication without written permission of the author. Many thanks to Julia Kursell and the Max Planck Institute for the History of Science for the invitation. Many thanks also for insightful commentary from Carrie Rentschler, Cornelius Borck, Mara Mills, Jennifer Daryl Slack, Greg Siegworth, Emily Thompson, Jody Berland, Darin Barney, Didier Delmas, and many others.

2 Ernest Glen Wever and Charles W. Bray, "Action Currents in the Auditory Nerve in Response to Acoustical Stimulation," *Proceedings of the National Academy of Science* 16 (1930), pp. 344-350, in particular p. 344.

3 Ibid., p. 345.

the response first diminished in intensity, and then ceased."[4] Wever and Bray's experiment thus illustrates the logical limit of the psychoacoustic subject – a subject literally wired into the system to pass electrical signals between brain and machine, a subject whose brain signals can be calibrated and correlated to vibrations in other sound technologies or out in the world. The cat's ear was like a condenser microphone on the front end of their system – it needed power (in the form of biological life) to operate. Invented during World War I, the condenser microphone was hailed as the "most nearly perfect electro-acoustical instrument in existence" and the origin point of modern acoustics. It used two charged diaphragms separated by a small air gap to transduce sound into electricity.[5] Unlike previous mics, it required a power supply. When the power was cut, the sound would fade away. So as the sound faded from their cat microphone, it demonstrated in the animal's death that life itself could power a phone or any other electro-acoustic system – perhaps that life itself *already did* power the telephone.

In theory, anyway, sound-reproduction technologies have always had a degree of interchangeability with aspects of human hearing. But in Wever and Bray, the model of interchange between ears and machines extends from the middle ear to the inner ear. This shift is paradigmatic, because it literally places sound-reproduction technology *inside* the mind's ear. To put a zen tone to it, the telephone existed both inside and outside Wever and Bray's cat and, by extension, people. Here, it is worth understanding their error. While Wever and Bray thought they were measuring one set of signals coming off the auditory nerve, they were actually conflating two sets of signals. The auditory nerve itself either fires or does not fire, and therefore doesn't have a directly mimetic relationship to sound outside of it – there is no continuous variation in frequency or intensity as you would have with sound in air. A series of experiments in 1932 revealed that the mimetic signals were coming from the cochlea itself. Called "cochlear microphonics," these signals were responsible for the sounds coming out of Wever and Bray's speaker in the soundproof room. As Hallowell Davis writes in a 1934 paper on the subject, "the wave form of the cochlear response differs from that of the nerve. From the latter we recover a series of sharp transients having the wave form and the polarity characteristics of nerve impulses [which fire 3-4000 times a second in the auditory nerve but only about 1000 times a second in the midbrain], while the cochlear response reproduces with considerably fidelity the wave form of the stimulating sound waves. Even the complex waves of the human voice are reproduced by it with the accuracy of a microphone, while from most nervous structures there is so much distortion and suppression of high frequencies that speech may be quite incomprehensible."[6] Davis thus suggests that nerves are bad circuits for reproducing sounds, but the cochlea is an excellent circuit for reproducing sound – much like a microphone. Davis and his collaborators' work on cochlear transmissions paved the way for a wide range of subsequent research, and cochlear microphonics are still important today. While they did challenge Wever and Bray's conclusions, Davis and his collaborators continued

4 Ibid., p. 346.

5 Acousticians and biographers quoted in Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America 1900-1930*, Cambridge: MIT Press, 2002, p. 95.

6 Hallowell Davis, "The Electrical Phenomena of the Cochlea and the Auditory Nerve," *Journal Of The Acoustical Society Of America* 6/4 (1935), pp. 205-215, quote at p. 206. Bracketed material added. See also L. J. Saul and Hallowell Davis, "Action Currents in the Central Nervous System: I. Action Currents in the Auditory Nerve Tracts," *Archives of Neurology and Psychiatry* 28 (1932), pp. 1104-1116; Stanley Smith Stevens and Hallowell Davis, *Hearing: Its Psychology and Physiology*, New York: John Wiley and Sons, 1938, pp. 310-332.

down the same epistemological path where ears and media were interchangeable; in fact one was best explained in terms of the other. Meanwhile, the brain's work of translation – from firing neurons into the perception of sound – became a major preoccupation of psychoacousticians as well and remains an open question down to the present day.

It becomes even clearer how important Wever and Bray were if we consider their relationship to the cats in their experiments and contrast it with the longer history of auditory research conducted on cats. Brain researchers interested in hearing have long used cats as research subjects. The cat brain is structurally similar enough to the human brain to allow for useful comparison, and cats were relatively inexpensive to both acquire and maintain in the lab (in comparison with, for instance, monkeys). What sets Wever-Bray apart is that they do not address the cat; they use its ear as a microphone, but the cat's consciousness is not ever in question. Of course, the cat itself could not have been "conscious" per se since its entire cerebral cortex and most of its midbrain had been removed – which makes earlier researchers' responses to their decerebrated cats all the more bizarre.

Despite the absence of anything like cat consciousness in the decerebrated animals, researchers treated their decerebrated cats as, well, cats. For instance, a 1922 article by Bazette and Penfield stated that "the most effective sound was a small scratching noise, and an animal would often react promptly by raising its head if a piece of paper was crumpled up at a distance of one or two yards. These sounds are similar to those made by a mouse."[7] In this example, the cats are clearly not enjoying a fully intersubjective relationship with the researchers. Certainly, the cats weren't enjoying it at all. At no time did the researchers imagine anything approaching a relationship of equality with the live animals they were cutting open. But the researchers did still think of their cats as, pardon the phrase, "cat subjects." The researchers compared their decerebrated cats' responses and behaviors to those expected of regular cats. Bazett and Penfield's invocation of the similarity of their scratching and crumpled paper sounds to "those made by a mouse" (as opposed to a squirrel, or some other animal) is a perfect example: here the researchers are imagining their research cat as they would any other cat – through the clichés of expected feline roles and interests. In fact, Bazett and Penfield were following the path set out by Forbes and Sherrington in 1914. In their article, the decerebrated cat is explicitly compared to a normal, healthy cat, and the entire study is based on the animals' own reaction. The cats are the object of the researchers' communications, whether the researchers are imitating dogs and cats, or lifting and replacing the cover on a canary's cage to control its singing in the lab. Forbes and Sherrington sought to get to essential truths of hearing by treating their decerebrated cats *as cats*.

A few words ought to be said about the violence of the decerebration procedure and the status of the cats. Scientists in the early 20th century were no doubt aware of the moral questions surrounding experiments on animals. Anti-vivisection campaigns first developed in the mid-19th century, and though psychology would not become a major target of the movement until

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7 Harvey Fletcher, *Speech and Hearing, with an Introduction by H. D. Arnold*, New York: Van Nostrand, 1929; E. Geoffrey Walsh, *Physiology of the Nervous System*, 2nd ed. London: Longmans, 1964, p. 317. H. C. Bazett and W. G. Penfield, "A Study of the Sherrington Decerebrate Animal in the Chronic as Well as the Acute Condition," *Brain* 45/3 (1922), pp. 185-265; A. Forbes and C. S. Sherrington, "Acoustic Reflexes in the Decerebrate Cat," *American Journal of Physiology* 35 (1914), pp. 367-376. Walsh does mention experiments done on monkeys and even a study of a human born without a cerebral cortex (p. 318), but it appears the majority of the work was done on cats.

sometime later, it is quite likely that the scientists involved had some sensitivity to the ethical issues involved. By the 1930s, public debate about animal experimentation – and its relation to experiments on people – had been raging for decades.[8] Bazett and Penfield's description of decerebration is most thorough, and they deal directly with the question of pain: "the Sherrington preparation seemed ideal for this purpose, since the question of any conscious sensation could be completely excluded, and in addition the preparation would remain quiet during the experimentation."[9] Which makes it all the stranger that both teams of researchers – Forbes and Sherrington, Bazett and Penfield – spent some of their time barking like dogs, crumpling paper to simulate mice, yowling like cats, and either bringing birds into the lab or chirping like birds themselves. Behind all this lies grand metaphysical questions about the seat of consciousness and subjecthood in the animal's brain and body and, specifically, the researchers' answers to those questions: why did the researchers write about the surgical procedure as if it left the animal with no consciousness, and then approach the animal as if it had some vestigial consciousness in their subsequent experimentation? The simple answer is that they were trying to solve an intellectual problem. In the studies of decerebration for the purposes of hearing research, authors did not know where auditory perception took place, and so they were doing their best to ascertain how much of audition was left when the mind was gone. But a deeper answer still might lie in the ambiguous social status of the animal as it lay on the surgical table, or afterward as it lay in a bath of warm water (since the part of the brain that regulates body temperature had been removed).

If one were to teleport back in time and ask the researchers why they used cats, their answers would probably have the ring of common sense and scientific reason: cats were cheap, convenient, similar enough to people, and pliable for the experiment. They were more or less interchangeable with other animals. Georg von Békésy is perhaps the best example of this tendency, since his research on cochleas led him to experiment on as many different animals as possible to view the movements of the cochlea's hair cells. Békésy believed the key to understanding hearing lay in the basilar membrane – a membrane that runs the length of the cochlea. He first constructed a mechanical model and later – using tools of his own invention – studied the movements of the basilar membranes in dead animals and in cadavers through a microscope. He would drain the cochlea of its fluid and replace the fluid with a salt solution that contained powered aluminium and coal. He would then flash light off the powdered solution, and he could view the interior working of the cochlea. As sound entered, a bulge would run along the basilar membrane, stopping near the base for higher tones and traveling all the way up for lower tones. Békésy would later win a nobel prize for this work. Perhaps emblematic was his study of elephant: when he heard that an elephant had died at the local zoo, he sent one of his assistants to retrieve the head. After his assistant made a trip to the zoo and two trips to a glue factory (the first time he did not cut far enough into the elephant's skull to get to the inner ear), he retrieved the animal's giant cochleas and Békésy was actually able to witness the movement of the hair cells first hand. Though the incident is recapped in full detail in later histories of auditory research, all he would say in his own published writing was that "by good fortune, the head of an adult elephant became available for

8 Susan Lederer, *Subjected to Science: Human Experimentation before the Second World War*, Baltimore: Johns Hopkins University Press, 1995, p. 31; Richard Ryder, *Animal Revolution: Changing Attitudes toward Speciesism*, New York: Berg, 2000, pp. 77-119.

9 Bazett and Penfield, "A Study of the Sherrington Decerebrate Animal," p. 186.

study."[10] Békésy's ecumenicism toward his animal subjects suggests an instrumental sensibility – in the universal traffic among the ears of the animal kingdom, a cochlea is a cochlea is a cochlea. Though much could be made of the elephant's captivity in life before its death in the zoo (and subsequent journey to the glue factory), Békésy's research continued the 19th century physiological tradition of gaining knowledge of the hidden processes of life through the dissection of the dead.

The realm of the living, meanwhile, was more fully suffused with ambiguity and contradiction. Beyond the stated intentions of the decerebrators and their protestations of disinterest as to the significance of the animals they used, we should ask what difference it made that cats figure so prominently in this tale. As Robert Darnton writes, "there is a certain *je ne sais quoi* about cats." In the decades before they became subjects of decerebration, cats were used for their mousing skills and their companionship, but they were also routinely tortured and killed (sometimes eaten), often *because* they were thought to have magical powers in both life and death – for fertility, for luck, for power, for protection. According to Jody Berland, cats occupy both sides of binary divisions like "human enterprise versus nature and wilderness, companionate animals or 'familiars' versus wild and edible animals, and domestic (feminine and familial) space versus public space."[11] Indeed, a first, earlier chapter in the history of acoustics follows this logic.
As Thomas Hankins and Robert Silverman note, Kitscher built a "cat piano" in 1650. Designed to amuse a bored Italian prince, pressing one of its keys would launch a spike into the tail of trapped animals selected for the tone of their cries.

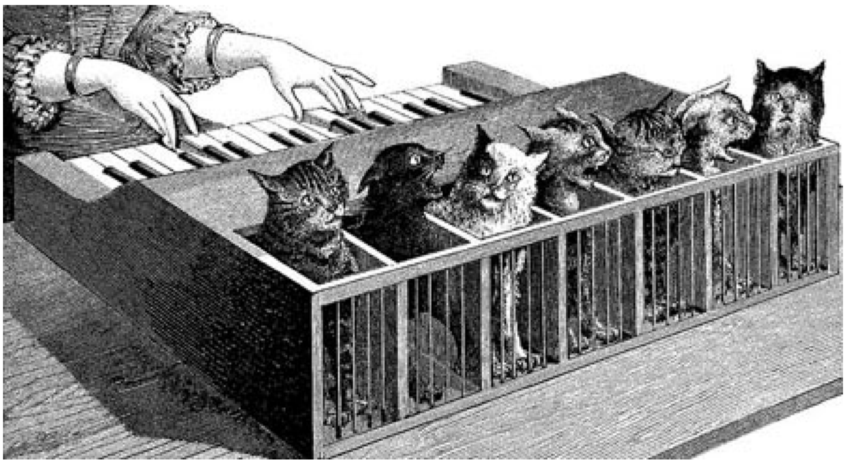

Fig. 1: The Cat Piano.[12]

[10] Georg von Békésy, *Experiments in Hearing*, trans. by Ernest Glen Wever, Toronto: McGraw-Hill, 1960, p. 508; Stanley Smith Stevens and Fred Warshofsky, *Sound and Hearing*, New York: Time Incorporated, 1965, pp. 54-56.

[11] Jody Berland, "Cat and Mouse: Iconographies of Nature and Desire," *Cultural Studies* (forthcoming), p. 7; Roger Darnton, *The Great Cat Massacre and Other Episodes in French Cultural History*, New York: Vintage Books, 1985, p. 89-94, quote at p. 89; Edmund Leach, "Animal Categories and Verbal Abuse," in: idem, *The Essential Edmund Leach*, ed. by Stephen Hugh-Jones and James Laidlaw, New Haven: Yale University Press, 2000, p. 333.

[12] Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination*, Princeton: Princeton University Press, 1995, pp. 73-78, figure at p. 73.

This particularly cruel instrument reappeared in 1725, when Louis-Bertrand Castel announced his ocular harpsichord. Castel used the cat piano as a joke to show that sounds were not beautiful in themselves but could only be made so through sequence and harmony. And ultimately human will. In a subsequent series of letters, Castel argued that music was something one learned to appreciate and that it was a purely human faculty. Thus, the cat piano showed that there is no such thing as cat music, only human music made through tormented feline cries.[13] Two centuries later, the tables would turn as inquiry moved from thought to perception. Cat consciousness was to some extent interchangeable with human perception, or for that matter electromechanical transmission.

If there is any historical relationship between the kinds of cat torture and murder one might find on St.-Jean-Baptiste Day in 18th century Paris or in a cat piano and the cold scientific "humane" vivisection of the physiologists and psychologists, it is through a relation of cultural descent. Max Weber describes the pursuit of wealth losing its dimension as religious "calling" and becoming an empty activity in itself over the long 19th century; one might say the same thing about people killing cats. The decerebated cats were unfortunate occupants of modernity's iron cage: stripped of their magic and mystique, they were still killed for human access to their powers. If there is a path from cat massacres to scientific study, it is a path of Weberian disenchantment.[14] Thus, one of the ways to understand decerebration is precisely as a kind of disenchantment of both cats and the process of hearing itself. For Claude Bernard, a pioneer in using vivisection for physiological research, stated it plainly decades before. In a discussion of experimental medicine fuelled by vivisection, Bernard wrote in 1865 that vivisection was very much about the almost ceremonial disenchantment of the body, the admixture of inside and outside, and a revealing of previously hidden processes.[15]

Though they share a trajectory, Wever and Bray differ from the decerebrators who went before them because throughout their experiments, they treat their cats as *anything but cats*. Their cats were microphones, transducers, and transformers for the simple telephone system they had rigged up between the lab and the soundproof room. They remained category violators, but in a thoroughly modern way. Consider the circuit diagram for their cat telephone:

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13 Ibid., pp. 74-78.

14 Berland, "Cat and Mouse," p. 14; Darnton, *The Great Cat Massacre*, pp. 89-94; Max Weber, The *Protestant Ethic and the Spirit of Capitalism,* New York: Charles Scribner's Sons, 1958, pp. 180-183. This kind of disenchantment is also visible in contemporary philosophy. When Deleuze and Guattari write that *"anyone who likes cats and dogs is a fool"* because these animals "invite us to regress, draw us into a narcissistic contemplation," their cats and dogs steal souls, turn adults into children, and in essence mesmerize their human companions. Once again, we have an iron cage for kitty: this time the magic is dressed up in modern psychoanalytic language, but is it any less rooted in superstition and mysticism than the common sense that told medieval builders to encase live cats in the walls of a newly built house? Centuries later, cats remain category violators. See Gilles Deleuze and Felix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia,* vol. 2, trans. by Brian Massumi, Minneapolis: University of Minnesota Press, 1987, p. 240.

15 Claude Bernard, *An Introduction to the Study of Experimental Medicine*, trans. by Henry Copley Greene, New York: Dover Publications, 1957, p. 18, p. 100. Bernard's first publication dealt with the chorda tympani, a nerve extending from the inner ear.

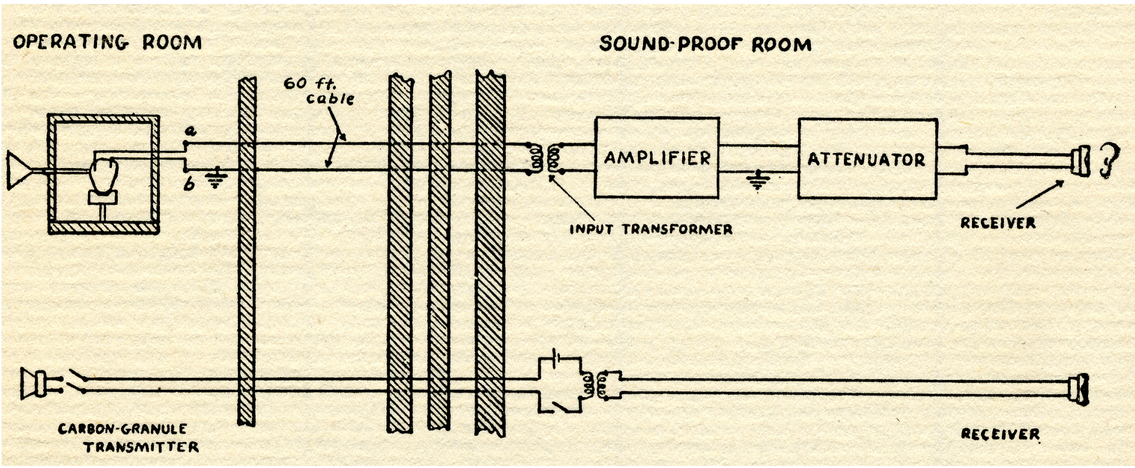

Fig. 2: Wever and Bray's Cat Telephone.[16]

The cat head at the upper left is simply part of the larger telephone system. In contrast to the human ear hanging off the end of the system in the soundproof room, the cat head is literally built into the system as a vital component. There is more than a little bit of Alexander Graham Bell and Thomas Watson mythology in the story of their experiment. Though I have not been able to find a record of the words spoken into the cat's ear, it is easy to imagine a re-enactment of the telephone's primal scene: "Bray, come here, I want to see you!"[17] Two researchers were separated by a hallway, one was situated in a room where no outside sound could reach, unless it came through the phone. The sound that came out of the speaker rendered the cat head just another node the circuit. In that moment the set of ideas that had been brewing for over a decade was made brutally literal: with the correct transformer in place, the ear was a component of the phone system, not its object.

In addition to being parts of a telephone system, Wever and Bray's cats were also model brains, as they attempted to make sense of the connections between the different parts of the ear, the nerves, and the brainstem. Their cats stood in for people, and for the faculty of hearing as such. Wever and Bray were clear on the matter: "The cat was selected as a suitable animal for this investigation. It stands fairly high on the animal scale, and we have casual and experimental evidence indicating its hearing to be comparable to that of man."[18] They were not the first to reach this conclusion. In his discussion of the telephone theory of hearing, Edwin G. Boring suggested their experimental approach, right down to Wever's study of cat hearing that immediately preceded his work with Bray.[19] Boring was primarily interested in *human* hearing. The cat was

16 Ernest Glenn Wever and Charles W. Bray, "The Nature of Acoustic Response: The Relation between Sound Frequency and Frequency of Impulses in the Auditory Nerve," *Journal Of Experimental Psychology* 13/5 (1930), pp. 373-387, figure at p. 378.

17 Though this is largely mythology, as the famous phrase was spoken in the middle of a series of tests on the telephone. See Robert V. Bruce, *Bell: Alexander Graham Bell and the Conquest of Solitude*, Boston: Little, Brown, 1973.

18 Wever and Bray, "The Nature of Acoustic Response," p. 374.

19 Edwin Boring, "Auditory Theory, with Special Reference to Intensity, Volume and Localization," *The American Journal of Psychology* 37/7 (1926), p. 157-188, in particular p. 181. See also Ernest Glen Wever, "The Upper Limit of Hearing in the Cat," *Journal of Comparative Psychology* 10/2 (1930), pp. 221-233.

merely an "e.g.," an example, a detour from the main event – the human brain and the human mind. If that weren't enough, more than one of the decerebration studies made note of the fact that a human baby was born without a cerebral cortex, and that it was subjected to a few tests (though it was not the subject of surgical experimentation).

What would it mean to take the psychologists at their word, that the cats were nothing more than stand-ins for people in these experiments? The substitutionist logic in Boring and Wever and Bray's writing, and work of the decerebrators before then, suggests a warrant for doing so. Another warrant comes from the paired histories of vivisection in medical research and anti-vivisection campaigns. In both cases, the progress from animal to human, and the consequent construction of the animal as stand-in for people is quite clear. "The condition of animals has long served as a political allegory for the treatment of humans."[20] Consider the condition of the head itself. After opening up the skull and severing the connection between the upper and lower parts of the brain, the "active electrode, usually in the form of a small copper hook, was placed around the nerve, while an inactive electrode was placed elsewhere on the body, in most cases on the severed cerebral tissue or on the muscle of the neck. In most experiments the left pinna was removed and a rubber tube sewed into the external meatus. The tube led to a funnel into which the stimulating sounds were delivered."[21] A closeup of the cat head in their telephone diagram renders the scenario quite clearly.

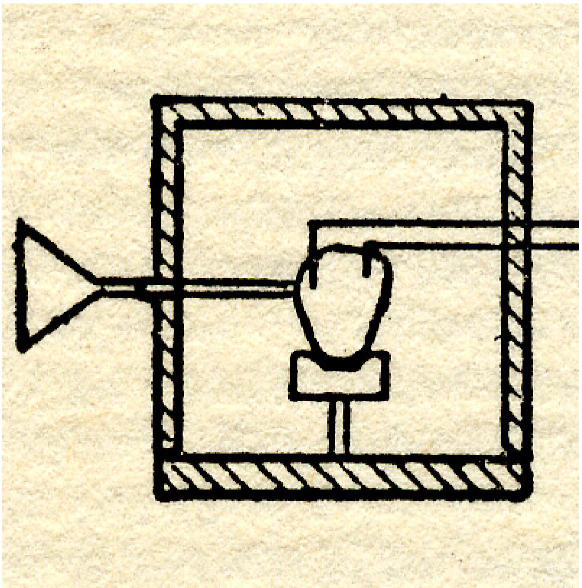

Fig. 3: Detail of Cat Head in Cat Telephone Diagram.

A telephone wired directly into the brain, a mouthpiece with a tube sewed directly into the head. What a perfectly coercive propaganda model! Here is a head, physically connected to a communication system, from which it cannot disengage itself and which it cannot turn off. Certainly, Wever and Bray were working in the point-to-point world of telephony and had

[20] John Durham Peters, *Speaking into the Air: A History of the Idea of Communication*, Chicago: University of Chicago Press, 1999, p. 242.
[21] Wever and Bray, "The Nature of Acoustic Response," p. 375.

completely discounted the cat's consciousness, and so perhaps this sounds extreme or far-fetched. But the implications of this arrangement for mass media like radio or film were already being drawn out by Wever and Bray's contemporaries in social psychology and other related fields. The famous 1929-1932 Payne Fund Studies sought to apprehend the effects of moviewatching on their audiences (especially children), while radio researchers were probing the same questions for their medium. Regardless of whether the motivation was social reform or more effective advertising and public relations, media were conceived in this age in terms of their effects on users and audiences, and those effects were considered to be substantial and direct. Later writers would criticize the findings and methodology behind so-called "hypodermic needle effects models", but the fantasy remains a powerful cultural script that has been replayed throughout the 20th century around comic books, television, video games, and the world wide web and social networking software. More importantly for our purposes, this hypodermic model also conceives of communication as primarily a function of transmission, an assumption it would share with the then-emergent metascience of cybernetics, a field that would come to treat life as another electromechanical process.[22] Consider Norbert Wiener's treatment of a kitten in *The Human Use of Human Beings*:

> I call to the kitten and it looks up. I have sent it a message which it has received by its sensory organs, and which it registers in action. The kitten is hungry and lets out a pitiful wail. This time it is the sender of a message. The kitten bats at a swinging spool. The spool swings to its left, and the kitten catches it with its left paw. This time messages of a very complicated nature are both sent and received within the kitten's own nervous system through certain nerve end-bodies in its joints, muscles, and tendons; and by means of nervous messages sent by those organs, the animal is aware of the actual position and tensions of its tissues. It is only through these organs that something like a manual skill is possible.[23]

The kitten's consciousness is mysterious and inaccessible to Wiener, but so are the signals in its nervous system, calibrated as they are to the animal's digestive system and the movement of a swinging spool of yarn. Despite the electronic language of circuits and messages, Wiener is not saying the kitten is a machine (though I imagine it as a machine every time I read this passage). He is saying that the distinction between a kitten and a machine does not matter for a theory of communication. And therein lies a line of descent from Wever and Bray to cybernetics. A cat is a phone is a cat, and a message is a message is a message.

There are many steps between Wiener and the modern day, but if you'll allow me to condense the entwined histories of psychoacoustics, cybernetics, and theories and technologies of communication into a single image, this one would do quite well:

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22 For a discussion of this moment, see Peters, *Speaking into the Air*, pp. 10-21. In fact, the paradigm had been in place by the mid-1920s. See, e.g., Max Schoen (ed.), *The Effects of Music*, New York: Harcourt, Brace and Company, 1927.

23 Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society*, New York: Doubleday & Company, 1954, p. 22.

Fig. 4: Napster.com logo.

A green-eyed cat with a sly smile listening to headphones: the Napster logo stares back. Called the "Kittyhead" by Napster executives, this is the second version of a logo designed by a friend of Napster founder Shawn Fanning. Fanning chose it simply because "it looked really cool." The manager of a branding firm puts it in more conventional marketspeak: "it's challenging and aggressive. It says 'we're the underdog. We're the new kid on the block and we are the antiestablishment.'"[24] Who really *can* tell a cat what to do, anyway? Here is a picture of a cat connected to a sound system that is supposed to be a mark of agency (for both company and consumer) and rebellion. And yet, it bears an uncanny resemblance to Wever and Bray's cat head, unconscious, decerebrated, wired and sewn into a system that it cannot comprehend or choose to leave. Of course, the "Kittyhead" is both everything Napster says it is and a reminder of the violence in the Wever and Bray diagram. In either scenario, we see beneath the visual metaphor of a cat with headphones the homology of interior and exterior systems – rebellious cats, rebellious listeners; communication networks, neural pathways. The homology between micro and macro is already presupposed, and the fundamental question of what it means to listen is already settled. However you read the Kittyhead, listening is above all else about one's position in the world of media, an attempt to negotiate it. It is about the balance among phenomena of administration and exchange, and the place of listening in that configuration. There is no "outside the system," at least not for these cats, because media are already "inside" them.

[24] Napster.com, *Partner Brand Usage Guide*. Available online at http://www.napster.com/NapsterUsageGuide.pdf (accessed 4 August 2006), 1. Melissa Heckscher, "And About That Strange Logo ..." *Entertainment Weekly*, 9 February 2001. Ironically, while it was subject to litigation from the RIAA for violating their intellectual property claims, Napster sued a California company for selling T-shirts with the Kittyhead logo on them. See "Napster Cat Attack," *Interactive Week*, 8 January 2001, p. 82.

The Resonance of "Bodiless Entities": Some Epistemological Remarks on the Radio-Voice

Wolfgang Hagen

Radio as a mass medium is primarily a product of its own resonances. To explain this thesis more specifically, two preliminary considerations are necessary. The first one relates to the fact that radio emerged twice: once in Europe and almost simultaneously in the United States and the two did not converge until the mid-1980s. Pursuing a short overview of what voice in radio is about, this paper takes a second look at the two different environments of resonance in which the voice has been embedded – radio and that which came before. First of all, I discuss the striking fact that, for at least one site of its emergence, the radio-voice in practice cannot be separated from the theory of voice that was established long before radio came into existence.

I.

We do not find the roots of voice theory in America, but in Europe. Here in the first part of the 19th century in London lived Charles Wheatstone, a, electrician, optician, gentleman, pioneer of British Telegraphy, experimentalist of his own kind, discoverer of the Wheatstone bridge and numerous other electrical switchings, examiner of the time of oscillations in discharging sparks, and inventor of countless other physical procedures. In 1837 Wheatstone coined the simple formula that the human vocality consists of nothing more than multiple occurrences of sounding resonances in our head cavities driven by the vocal chords.[1] Thirty years later, Hermann von Helmholtz referred to Wheatstone's considerations, explaining the incidents in our oral cavity more precisely:

> Je mehr die Mundhöhle verengert ist durch die Lippen, die Zähne oder die Zunge, desto entschiedener kommt ihre Resonanz für Töne von ganz bestimmter Höhe zum Vorschein, und desto mehr verstärkt sie dann auch in dem Klang der Stimmbänder diejenigen Obertöne, welche sich den bevorzugten Graden der Tonhöhe nähern; desto mehr werden dagegen die übrigen gedämpft.[2]

Worthy of note for media historians might be that Charles Wheatstone was a good friend of the teacher of the deaf, phonologist Alexander Melville Bell, the discoverer of the telephone. Father Melville and son Alexander Graham visited Wheatstone quite often, among other reasons because of his replication of the famous speaking machine of Wolfgang van Kempelen. This Wheatstonian replica encouraged numerous rather amateurish experimentations in the Bell family, including

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1 Charles Wheatstone, "On the Vowel Sounds, and on Reed Organ-Pipes" (London and Westminster Review, 1837), in: idem, *The Scientific Papers of Sir Charles Wheatstone*, London: Taylor and Francis, 1879, pp. 348-367, 360.

2 H(ermann Ludwig Ferdinand von) Helmholtz, *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*, Braunschweig: Vieweg, 1863, p. 171.

slaughtering cats and preparing their glottis. Speaking machines had long been objects of desire in the Bell family.

During his hasty move from England to Boston in 1872, son Alexander took little more with him than the aforementioned *Lehre von den Tonempfindungen* by Helmholtz. Alexander was obsessed by an illustration in the book of what might be called a tuning fork resonance machine. This machine in Helmholtz's book was supposed to demonstrate how vowels could artificially be put together from simple tones, but in Alexander Graham Bell's mind it apparently produced the *idée fixe* that artificial vowels could be communicated by a telegraph. To put it in modern terms, one could say that Bell might have seen in Helmholtz's drawing a portable synthesizer for electrically produced speech. This serious misreading was caused by the fact that Bell couldn't read German. But combined some years later with the obsessed spiritism of his assistant Watson, his misunderstanding paved the way to the discovery of the telephone in June 1875, which was a casual and contingent, and at the same time a coherent and logical event.[3]

The 19th century saw plenty of explorations and discoveries in the provenance of resonance. As it started with Chladni's sound figures in 1802 and closed with Röntgen's X-rays in 1895, the 19th century could be called the *century of the frequency*. Of course, in terms of mathematical frequencies, oscillations, sinusoidal curves, periodic functions, and so forth, around 1800 a solid inventory of analytical mechanics was already available. Most of the work had been done by Leonard Euler at the Academy of St. Petersburg, where the legendary vowel-reward question was advertised in 1779: "First. What is the nature and character of the sounds of the vowels A E I O U, so different from each other? – Secondly. Can an instrument be constructed like the *vox humana* pipes of the organ, which shall accurately express the sounds of the vowels?"[4] The prize was given to a man named Kratzenstein, who had submitted a set of organ pipes for each vowel. This story continued with the van Kempelen apparatus, its replication with Wheatstone, Helmholtz's work on vowels and its misreading by Bell leading to the telephone apparatus.

The question of how to generate voice sounds may stem from the 18th century, and in terms of frequency theories, the definite answers were already known in the 19th century. However, the 19th century was not only the century of frequency, but also of *Geist* ("spirit," as the word translates rather insufficiently). In the 19th century *Geist* and frequency were closely related in a deep, romantic resonance of an inerasable kind. The question was: What lies behind all these ideas of frequency and its mathematical formulas that Euler and Fourier had developed? What is the substance of all of this? There had to be something in nature itself that existed in a kind of ideal parallel to mathematics. The name of this "something" came into being around 1800. Hegel described it in 1804 in Jena:

> Der Äther [also] durchdringt nicht [nur; W.H.] Alles, sondern er ist selbst Alles; denn er ist das Sein. Er hat nichts außer ihm und verändert sich nicht, denn er ist […] die flüssige und untrübbare Durchsichtigkeit. Dieses reine Wesen aber […] ist nur die schwangere Materie,

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3 Cf. Wolfgang Hagen, "Gefühlte Dinge: Bells Oralismus, die Undarstellbarkeit der Elektrizität und das Telefon," in: Stefan Münker and Alexander Roesler, *Telefonbuch: Beiträge zu einer Kulturgeschichte des Telefons*, Frankfurt/M.: Suhrkamp, 2000, pp. 35-60.

4 Wheatstone, "On the Vowel Sounds", pp. 348-367, 352.

> welche als absolute Bewegung in sich die Gärung ist, die ihrer selbst als aller Wahrheit gewiß […] in sich und sich [selbst; W.H.] gleich bleibt.[5]

For Hegel, *Geist* and being, "das reine Wesen," spirit and ether are intermingled in a kind of psychophysical parallelism. In this dialectically woven unity, the ether is defined as hard as diamonds, although at the same time invisible and as fully transparent as the most abstract nothing. Nevertheless it has a weight, even a measurable one, as William Thomson affirmed some decades later. But again, ether can let everything ponderable pass through itself without any traces being left. Heinrich Hertz's radio papers in the late 1880s convey the huge efforts Hertz had to make to fix and reproduce his radio waves, whilst still being deeply immersed in the magic circuit of the ether given by contemporary physics in Germany, which couldn't explain his data.

In the light of this epistemological horizont of ether, frequency, and *Geist*, no one should be surprised that the voice, as the most complex phenomenon of resonance, also came to be understood as an object of psychophysical ideal. If we focus on continental Europe, first Theodor Fechner (1801-1887) comes into sight, then after him, Wilhelm Wundt (1832-1920), and finally, Eduard Sievers (1850-1932). All three theoreticians deeply rooted their work in the concept of psychophysical parallelism. Concerning the voice, these theories predict that, in the physiological nature of the human body, there is nothing vibrating, twitching, or just happening that does not automatically evoke a psychical reaction, and vice versa. There are, says Wundt, no psychical reactions whatsoever that are not correlated with a corporeal expression. Neither the expression of thoughts nor the communication with the other, the expression of bodily motions alone should be the primary reason for a vocal articulation according to Wundt and Fechner. With the 1855 invention of the laryngoscope by the Spanish opera singer Manuel Garcia, the chance had come to get deeper into the details of the voice-building organs in the pharynx than Helmholtz would ever do. The preconditions were set for the lifelong experiments and explorations of the phonetician Eduard Sievers, who mapped the whole complex process of sounding of the voice in every possible detail.

"Rhythm and melody" of human speech, wrote Sievers, "are […] regulated simultaneously by certain accompanying and periodic internal processes of motion or representations of motion, which I will call vibrations after their overwhelmingly most common appearance."[6] On the basis of this inner/outer parallelism, Eduard identified categories, groups, and subgroups of vocality, such as vowels and consonants, voiced and unvoiced plosives, alveolar and palatal fricatives. For all of these Sievers defined ideal dimensions that were again centered around the concept of resonance.

After having done so, Sievers was ready to normatively define standards. In April 1898 he met with leading theatre directors and Theodor Sieb, a scholar of the German language, to commit to a "regulation for the pronunciation of German on stage" ("*Regelung der deutschen Bühnenaussprache*"). The resulting book, *Deutsche Bühnenaussprache*, was, until the 1960s, not

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5 Georg Wilhelm Friedrich Hegel, *Jenaer Realphilosophie*, Hamburg: Meiner, 1967, p. 4.

6 W. E. Peters, "Stimmgebungsstudien," *Psychologische Studien* 10 (1918), pp. 387-570, 388: „werden […] gleichzeitig durch gewisse sie begleitende und periodisch verlaufende innere Bewegungsvorgänge oder Bewegungsvorstellungen geregelt, die ich nach ihrer überwiegend häufigsten Form […] als innere Schwingungen bezeichnen will."

only a primer for actors but also the ultimate standard text for all public speaking, as well as for education; and, of course, for speaking in radio, as we will shortly see.

With these important regulations the parallelistic paradigm of the voice became political. Its main watchword from then on was "*Reinheit*," that is "cleanness" or "purity." However, in German I should really say: "*Rrreinheit*," because the rule states: "Es ist in allen Fällen durchaus das Zungenspitzen-r zu fordern; nur dadurch kann den schon sehr stark eingebürgerten Mißbräuchen begegnet werden, statt des r vor dem t ein ch zu sprechen (z. B. wachten statt warten, Pfochte statt Pforte) oder Wuam statt Wurm, oder Mutta statt Mutter."[7]

With *Reinheit*, which must now be pronounced with a rolling "r," the episteme of resonance comes once again to the center. To be pure in one's own speaking meant to build clean and pure vowels, which are clean only if they are articulated in a proper resonance of the mouth and in the head cavities, gaining a state called "self-tone" or "own-tone." As Siebs wrote:

> Für die Vokale kommt außer dem Stimmton der Eigenton in Betracht. Die oberhalb des Kehlkopfes liegende Mundhöhle und bisweilen auch die Nasenhöhle, zusammen als Ansatzrohr bezeichnet, bilden für den im Kehlkopfe erzeugten Stimmton einen Resonanzraum; er kann […] die mannigfaltigsten Formen annehmen, und ihnen entsprechen die verschiedenartigen Eigentöne, die Klangfarben der einzelnen Vokale.[8]

Pure vowels in Siebs's sense can only be natural tone resonances, which are precisely measurable in terms of ideal physical mouth-cavity states. In other words, as an expression of resonance, the voice has to be both individual and ideal at the same time. Everyone produces their own self-tone vocals, but their scales are of absolute degrees as well. Voice as a means of social relationship and communication was faded out completely. Such aspects first came to light with Karl Bühler in the 1930s – against the Wundt and Sievers tradition – and shifted from there to the linguistic school of Prague, and then later to the psychoanalytic school of Jacques Lacan.

II.

The politics of voice were already obligatory when German radio started its broadcasting – nomen est omen – in 1923 from the Voxhaus on Potsdamer Platz in Berlin. The book *Deutsche Bühnenaussprache* from 1900 was reedited in 1931 under the title *Deutsche Rundfunkaussprache*, although no one in the radio audience spoke in that manner, except the great figures on the Reinhardt stages such as Josef Kainz, Alexander Moissi or Friedrich Kayssler, or some gentle schoolteachers or clergymen in the cathedrals. In fact, with radio – the first electromagnetic medium – the politics of the returned to the metaphysical realm. The ether as the essence of the absolute being bearing the extrasensory spirit of all the logic of frequencies was now thought of as being voiced through the radio.

Richard Kolb, the most influential theoretician of radio in the Weimar Republic said in 1932:

> Die Funkwellen sind wie der geistige Strom, der die Welt durchflutet. Jeder von uns ist an ihn angeschlossen, jeder kann sich ihm öffnen, um von ihm die Gedanken zu empfangen, die die

7 Theodor Siebs, *Deutsche Bühnenaussprache*, 8th and 9th ed., Berlin, Köln: Ahn, 1910, p. 60.
8 Ibid., p. 25.

> Welt bewegen. Der unendliche freie Geistesstrom trifft auf unseren kleinen, geschlossenen, mit Energien gespeisten und geladenen Denkkreis und versetzt ihn durch das feine Antennennetz unserer Nerven in Schwingung. […] Der unsichtbare geistige Strom aber, der vom Ursprung kommt und die Welt in Bewegung brachte, ist seinerseits in Schwingung versetzt, gerichtet und geleitet vom schöpferischen Wort, das am Anfang war und das den Erkenntniswillen seines Erzeugers in sich trägt.[9]

Kolb was the ideological guiding star of radio from the early 1930s until the 1970s in Germany. Among his adherents we must count almost every important radio practitioner, for example, Fritz Walter Bischoff, one of the most important radio play producers in Weimar, and Heinz Schwitzke, who had been head of the radio drama department in the Norddeutscher Rundfunk in the reconstruction era of the 1950s. Kolb's theory of the so-called "bodiless essence of the voice" (*körperlose Wesenheit der Stimme*) alleged that the radio could let the inner pureness of the voice rise again in the listener's mind. Broadcasting the voice, Kolb said, can produce a special kind of meta-personality in the listener's mind "in the shape of bodiless beings" (*in Gestalt körperloser Wesenheiten*). Kolb describes this idea as follows:

> Der über die Erde hinausgeschleuderte freie Strom der Funkwellen erhält die Modulation durch das vom Hörspieler erzeugte Wort, das Sinn und Richtung durch den Dichter erhielt. Die elektrischen Wellen treffen den Menschen, gehen durch ihn hindurch, und es wäre nicht absurd zu denken, dass der Mensch Nerven hätte, die die Wellen unmittelbar aufnähmen und im Gehirn zur Wahrnehmung brächten.[10]

As far as German radio history is concerned, the impact of these theories, when applied in practice, turned against the medium itself. The medium suffocated from the very beginning. Radio in Germany didn't start as a mass medium nor did it emerge as such in its first decades. As Hans Bredow explicitly defined it, radio started as a "cultural instrument." No politics, no quarrelling of political parties, and no real discussions were carried out in the program. Even the parliament almost completely ignored the medium. The elevated radio voices instead gave lectures and readings that were well-prepared and censored in advance. If street battles were raging outside or a minister was killed on the footpath – even if half of the Grunewald stood in flames – in the democracy of Weimar, the radio remained silent to all of that. In my view the reason is an epistemological one: the psychophysical politics of voice and its self-tone are non-party and trans-social politics. Of course, to emphasize the apoliticality of the voice was in itself of great political power. The first man who recognized this deep ambiguity was Goebbels in his legendary sentence written down in his diary in February 1933: "[Radio] is an instrument of mass propaganda, which today has not been appreciated yet in its efficiency. At any rate our enemies didn't know what to do with it"[11]

Goebbels's voice was a comparatively bad one, but on the radio he always spoke informally and live. In early 1933 he could be heard almost every day. He never rolled his "r", whereas the

9 Richard Kolb, *Das Horoskop des Hörspiels*, Berlin: Hesse, 1932, p. 2.
10 Ibid., p. 53.
11 Joseph Goebbels, *Die Tagebücher von Joseph Goebbels: Sämtliche Fragmente*, vol. 2, part 1, ed. by Elke Fröhlich, Munich: Saur, 1987, p. 372.

"Führer" rolled his "r" all the more. "There Hitler, here reportage,"[12] wrote Goebbels in his diary. It was not the explicitness of Hitler's speeches, but the medial difference between the long radio announcements that Goebbels made, and the hotheaded tirades of Hitler that followed, was the key to the formula with which the Nazis brought the masses to their side in early 1933.

But the orgy of the Führer's speeches didn't last very long. In the radio studio, Hitler couldn't even articulate one understandable sentence. He never did a studio recording. What Hitler obviously needed was never considered in the psychophysical theory of the voice. He needed the resonance of the other, in his case the resonance of a kind of roaring mass. Therefore in 1934, Goebbels, who was also in charge of the radio programming, took almost all of the Führer speeches out of the program and switched it over to "light music," which was one of his neologisms.

III.

In contrast, a quick glance of United States radio history shows a stark contrast to that of Europe. Because radio in the United States started as amateur radio-telephony, the whole system is informed by a completely different politics of the voice. Not the resonance of the self, but the resonance of the other was epistemologically imprinted into the medium from the first day. Even today American radio stations still have call signs as if they were sea-broadcasters communicating with coastal stations: WABC, KWA, WEAF, KDKA, 8XK.

Because they were seen (and licensed) as a system of wireless telephony, American radio stations had to broadcast for the first seven years over almost only one single frequency. There were hundreds at the same time – 700 stations in 1925 – and on each channel voices sounded different. The US radio, from its beginning until far into the 1960s, was characterized by an egregious polyphony and poly-voiced variety that did not exist in other regions of the world during these decades.

Starting in 1925, the so-called serials emerged. These were short-form radio plays broadcast daily that later evolved into the daily soap operas that we know from television, a shift that happened when almost each and every radio program was moved into television in the mid-1950s. In the time before that, American old-time radio collectors have counted that there were 6,000 different serials for the period from 1925 to 1960, each containing dozens, hundreds, and sometimes thousands of episodes. During one of the biggest crises of the American society – the Great Depression in the 1920s and 1930s – it was the radio with its dialectal, multi-ethnic, and polyphonic vocality that held the nation together. That is Susan Douglas's point in her related studies and I agree with her.

"Amos 'n' Andy," as an example, is the first and oldest serial in the history of the American radio, done completely in the colloquial language of the South, telling of the immigration-like travels of two African-Americans in their own country, from South to the North, over hundreds of episodes. It is done in the heaviest "black" Birmingham slang, but all the way played, spoken, and vocalized by two white men who play Amos and Andy. What we hear is a blackface comedy, a vocal slapstick, so to speak, in the tradition of Vaudeville, mixed up with the huge betrayal of

[12] Ibid., p. 369.

whites speaking as blacks. But apparently they spoke so perfectly that in the first 35 years not one anti-racist petition (there were a few) could lessen the huge success of Amos and Andy.

In a study for Lazarsfeld in 1942, Rudolf Arnheim analyzed over 45 daily serials broadcast in New York, all featuring vocally simulated personalities. The huge success of these serials had a simple reason: in a land of immigrants everyone sounds like a stranger in his own country. Therefore radio voices reproducing this situation are able to develop what anthropologists might call the "pathic function" of communion. The pathic function of the voice, which was first worked out by Malinowski in his Trobriandian studies[13] and later refined by Jacobson and Lacan, contains the most important aspect of the voice as we find it in radio.

The crucial point seems to be that the multicolored ventriloquism of voices in the United States accomplished a politics of voice that certainly cheated the listeners with simulation and pretense but never gave them more or less than they expected. American radio history is full of thousands of vocal personalities acting like impostors who used their voices to create new personas. But as we all know achieving a persona or even becoming a nation seems to be a process of repeated failures that nevertheless must continue and that brings forth social, and in this case, media, structures that provide a sustaining formality. The impact of the famous period of radio serials didn't change very much when the serial hero was replaced in the 1950s by deejays, such as Alan Freed and Wolfman Jack. Here we hear, as Michelle Hilmes stated, radio voices being mutated into totem animals.

The simulation of vocal personalities in radio works so well because the listeners dissimulate the radio simulation and in doing so admit and reproduce the medial structure they are subjected to. The reason for this is not stupidity. I would suggest that it works because, as radio listeners, we are simply not seeking, as Sievers or Sieb said, our self-tone (*Eigenton*). By the way, anyone who has ever heard his or her own recorded self-toning voice will remember the shock of listening to one's self for the first time. What we have learned about the voice through the media of the voice in the 20th century is that vocalized speaking seems to be always a quest for one's own voice, but this search consists of desiring the voice of the other. In this way, Karl Bühler was completely right when he said that a vocal expression is always a phenomenon of resonance and a reproduction of the experience of resonances. This desire to 'have the voice' always remains unsteady because a fulfillment of this desire will never happen. The desire is insatiable.

The extraordinary polyphonic variety of deejays and serial heroes in American radio can teach us to what extent the search for the voice of the other is rooted in the imperceptibility of the own voice. Everyone easily surrenders to the enjoyment of being very deeply betrayed and misled by other voices. Only those who are not deceived fail, Lacan once said. This is very true, especially in regard to all those voices to which we surrender in fascination.

But coming to the very last point, vocal politics like these didn't make the big money – not even in the U.S. radio business. In the mid-1970s the music industry took command. For the music companies, radio programs were nothing more than intelligent amplifiers of consumption. Very successful, one has to say, because they tripled their sales figures twice in thirty years. But to strengthen that process, the irritating variety of ventriloquism of thousands of American deejays

[13] Bronislaw Malinowski, "The Problem Of Meaning In Primitive Languages," in: Charles K. Ogden and Ivor A. Richards, *The Meaning of Meaning: A Study of The Influence of Language Upon Thought And of the Science of Symbolism*, 10th ed. London: Routledge & Kegan Paul, 1956, pp. 296-336.

had to be removed. Eighty percent of the Americans still listen to two and a half hours of radio, and 80 percent of the 13,000 stations in the United States play mostly music. That is all comparable to Germany of today. Very rarely can a voice be heard talking (except in the 20-percent market of talk-only-radios), and the programs sound so similar that tuning to another station almost doesn't make any sense. Today we face the paradox that, in radio, an almost voice-free environment can satisfy the radiophonic desire for pathic communion with a voice well enough. The logic of the voices in radio works most likely as the mechanisms of advertising operate, even if there is no advertising spot on the air: radio in itself proposes something from which everyone knows that the opposite is meant or the main thing is missing. Theoreticians of system theories could say that radio is a system getting its stability out of the weakest resonances. For most radio stations in Europe or America, this seems to be the case.

VLF and Musical Aesthetics

Douglas Kahn

VLF is short for Very Low Frequency electromagnetic phenomena occurring naturally in the atmosphere and magnetosphere, larger than global phenomena that are available to the ear without having to be transposed either up or down as with, say, the signals associated with radio astronomy.[1] They occur at one of the two places on the electromagnetic spectrum that intersect with human vision and audition, the other being visible light. Unlike light, they require transduction, but only require simple technology, just one step up in artifice from the natural transducers of auroral sound, and only a mirror image of the transduction involved in human hearing. The best known type are whistlers, which are produced primarily by the full spectrum electromagnetic burst of lightning, reflecting between the earth and ionosphere, escaping to spiral around flux lines in the magnetosphere great distances from the earth. They can travel from one hemisphere to the next and at times bounce back and forth between hemispheres. VLF waves themselves are so long that, despite traveling at the speed of light, they fall within the human audible range.

There are three ways to approach VLF and musical aesthetics. The first is to ask what role musical aesthetics might have played in the first encounters and subsequent scientific investigations of VLF and related phenomena. The second is to compare these with a range of concurrent discourses on musical aesthetics. I will concentrate on the first and only mention the second. The third would be to examine the actual artistic use of VLF, but since this did not occur until 1968, it falls out of the timeframe of this workshop.

The first encounters with what would eventually become known as VLF took place starting in 1876 when telephones were attached to telegraph and telephone lines and submarine cables. The scientific literature began in earnest on the heels of World War I with the first German paper published by Heinrich Barkhausen in 1919 and the first British paper by Thomas Lydwell Eckersley in 1925. The aesthetic, military, technological and cosmological scene of this difference between these two encounters is available in "To the Planetarium", the concluding section of Walter Benjamin's "One-Way Street." In this passage he asserts that the ancient commune with the cosmos had lapsed from one conducted through collective *ecstatic trance* (*Rausch*), into the modern's solitary and distanced, optical stance of astronomy, and warned of its terrible revanchism on the fields of World War I, "which was an attempt at new and unprecedented commingling with the cosmic powers."

> Human multitudes, gases, electrical forces were hurled into the open country, high-frequency currents coursed through the landscape, new constellations rose in the sky, aerial space and

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[1] The more precise term would be *audio frequency range electromagnetic phenomena*, a range dominated by but not limited to VLF. I will privilege brevity over precision.

> ocean depths thundered with propellers, and everywhere sacrificial shafts were dug in Mother Earth. The immense wooing of the cosmos was enacted for the first time on a planetary scale – that is, in the spirit of technology.[2]

For the moderns, somewhere between detached astronomy and ecstatic trance lies the belittled "poetic rapture of starry nights," a commune if not normally a communal experience, in the sense of social collective.

Starry nights on the telephone

Communication technologies need not be fully equated with communication. The early telephone receiver was not merely a means for humans to converse, it was also considered to be a sensitive scientific instrument. John Joseph Fahie, in his 1899 book on the history of wireless telegraphy says the first period in the evolution of the technology was characterized by good ideas and unsubstantiated claims, followed by the second, *practicable* period once the telephone was attached to telephone and telegraph lines.[3] "The introduction of the telephone in 1876 placed in the hands of the electrician an instrument of marvelous delicacy, compared with which the most sensitive apparatus hitherto employed was as the eye to the eye aided by the microscope."[4] When trained on "different forms of atmospheric electrical discharges – and they are many – it has a language of its own, and opens up to research a new field in meteorology."[5]

From the very beginning, in 1876, two classes of sound were heard over the telephone: *human-made sounds* – telegraphic code first heard wirelessly when Guglielmo Marconi was two years old and music and voice when Reginald Aubrey Fessenden was ten years old –, and *naturally-occurring earth and atmospheric sounds*. Of the many who heard the latter was Thomas Watson, Alexander Graham Bell's assistant. He may have been the first, if only because he initially had privileged

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2 Walter Benjamin, "One-Way Street," in: *Selected Writings*, vol. 1, *1913-1926*, Cambridge, MA: Harvard University Press, 1996, pp. 486-487. The English translation of *Rausch* to "ecstatic trance" gives too much of a ritualistic Dionysian trance 'n' dance inflection to term, whereas it could no doubt also include a more sedate and expansive rendering of "oceanic." The passage is Benjamin's nod to Ludwig Klages and his "anthropological materialism" in full operation, where we neither know who the "ancients" might be nor can we estimate the tenor of their experience. We can say that it is a premodern one outside commodity logic and circulation, and lends itself to a spatialization off the planes of photography and cinema, past dioramas and panoramas, "to the Planetarium." It plays less in the transit of distance, such as the shift and destruction of the aura in his "Work of Art…" essay, and more in a dynamic union and dissolution: "For it is in this experience alone that we gain certain knowledge of what is nearest to us and what is remotest from us, and never of one without the other." Such negotiation of distance also suggests that Benjamin's commune with the cosmos was configured from more terrestrial, corporeal desires, erotic commune and dissolution of self, as stated in the "Nearness and Distance" section of "Outline of the Psychophysical Problem," (ibid., p. 397ff.) written during the same period as *One-Way Street*, and existing in the same neighborhood as the so near and yet so far address of Asja Lacis. Thus, the "ancients" need not be unknown, nor pawned off to creatures of "weak messianism", but can be contrasted with imperial, militarized and other patently destructive desires and engagements. U.S. fighter pilots woo the cosmos over Iraq with Jesus, pornography, rock and an explosive spectacle absented of suffering.

3 As Charles Süsskind has stated, "Observations of electromagnetic-wave propagation from man-made electrical disturbances have been made probably for as long as there have been means for producing moderately large sparks." Charles Süsskind, "Observations of Electromagnetic-Wave Radiation Before Hertz," *Isis* 55/179 (March 1964), pp. 32-43, quote on p. 33, including when, "in 1780, Luigi Galvani observed that sparking from an electro static generator could cause convulsions in a dead frog at some distance from the machine."

access to the telephone. In 1876 he listened at night for hours over a half-mile long iron line running over housetops of Boston. Reminiscing half a century later, Watson wrote:

> There were no trolley car or electric light systems to send their rattling current-noises into our wire and the only other electric circuits in constant use were the telegraph wires, the currents in which, being comparatively weak and easily recognized as the dots and dashes of the Morse code, did not trouble us.
> This early silence in a telephone circuit gave an opportunity for listening to stray electric currents that cannot easily be had today. I used to spend hours at night in the laboratory listening to the many strange noises in the telephone and speculating as to their cause. One of the most common sounds was a snap, followed by a grating sound that lasted two or three seconds before it faded into silence, and another was like the chirping of a bird. My theory at the time was that the currents causing these sounds came from explosions on the sun or that they were signals from another planet. They were mystic enough to suggest the latter explanation but I never detected any regularity in them that might indicate they were intelligible signals. They were seldom loud enough to interfere with the use of the telephone on a short line.
> […] I, perhaps, may claim to be the first person who ever listened to static currents.[6]

He speculated that these sounds were produced by the sun or by an extraterrestrial species, although he did not put much emphasis on either and would not have listened for hours on end for the purposes of identification alone. He instead related his experience to his lifelong engagement with nature. As a child he would go up on the roof of the stable and sit there, "alone in the twilight with a delightful feeling of being part of the sky and on good terms with God." Thus, for Watson, his nighttime VLF listening sessions were the auditory equivalent to this "poetic rapture of starry nights." This idea of the cosmos led Watson to Mother Earth, the ecological moment in Benjamin's Planetarium. He went on to formalize a philosophy of earth divinity in a pamphlet called "From Electrons to God," which was preceded by two essays, "The Earth, A Vast Orchestra," and "The Religion of an Engineer," all of them bearing the influence of Gustav Fechner and his *The Little Book of Life after Death*. It is in these later writings where Watson applies musical metaphors and aesthetics to the cosmos. The music derives from an evolutionary, particle-wave melding of the atomistic combinatory properties of electrons with an extant and universally vibratory ether.

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4 John Joseph Fahie, *A History of Wireless Telegraphy, 1838-1899*, Edinburgh: William Blackwood and Sons, 1899, p. 79.

5 Fahie, *A History of Wireless Telegraphy*, pp. 79-80. According to Thomas A. Watson, Bell was driven by the idea that "he would soon be able to *talk by telegraph* […] 'Watson,' he said, 'if I can get a mechanism which will make a current of electricity vary in its intensity, as the air varies in density when a sound is passing through it, I can telegraph any sound, even the sound of speech." First try was the harmonic telegraph. "It was an apparatus with a multitude of tuned strings, reeds and other vibrating things, all of steel or iron combined with many magnets." Thomas A. Watson, *Exploring Life: The Autobiography of Thomas A. Watson*, New York: Daniel Appleton and Company, 1926, p. 62.

6 Watson, *Exploring Life*, pp. 80-82. See also p. 121, a reporter from the *Lawrence American* newspaper in Massachusetts cited only as Mr. Fisher, writes of a telephone lecture/demonstration: "About 10 p.m. Watson discovered the "Northern Lights" and found his wires alive with lightning, which was not included in the original scheme of the telephone. He says the loose electricity abroad in the world was too much for him."

> Every electron and every atom of the earth, from its center to the farthest limits of its atmosphere, is alive and sings its part in earth's stupendous music.[7]

> The universe is made of a single eternal substance, eternally vibrating in an infinite range of frequencies. Everything we know is something vibrating: the universe is like a vast orchestra playing an eternal music of millions of octaves combined into an infinite variety of melodies and harmonies. These vibrations are the universal Life, all under the control of a single eternal Law which causes harmonic vibrations to unite. From every union of vibrations under this Law something new emerges. From this Law, which I call Harmonic-Union-Creation, acting on the universal Substance everything in the Universe from electrons to God has emerged.[8]

Watson had, in the intervening years, become interested in a variety of occult writings, and his musical, vibratory and ethereal cosmos certainly reflects some of Theosophy's reworking of Hindu cosmogony.[9] His more original contribution to musical aesthetics is summed up in his statement, "I, perhaps, may claim to be the first person who ever listened to static currents." Although he was not listening to what he thought was music, and was not yet considering every vibration to be part of the *Vast Orchestra of Earth*, he was listening to what would start to be incorporated into musical aesthetics with Luigi Russolo's *Art of Noises Manifesto* of 1913, furthered in John Cage's musical aesthetic of listening (where music does not have to be made for it to exist), codified beginning in 1968 in Alvin Lucier's musical incorporations of actual whistlers and sferics, and socialized since the 1960s in subcultural interleaving of noise and music. Moreover, he seems to have been the first person to listen directly to sounds of the signal, and was thus at an important juncture of the shift in musical cosmology and cosmology from the longevity of the Pythagorean acoustical imaginary to an electromagnetic real; from a vibrating string to the antenna; from vibration to the signal. This was a class of cosmological signal first heard over the antennae of telegraph lines, measured over fifty years later in the lonely noise of Karl Jansky, and then expanded to the origin and evolution of the universe with the pervasive static of the cosmic microwave background.

The cosmic battlefield

Two scientists, one German and one British, were tutored by *electrical forces hurled into the open country, high-frequency currents coursing through the landscape*, as Benjamin described the fields of World War I, and went on to woo the cosmos on a planetary scale through writing the first papers on VLF. The scientific literature begins with a 1919 paper by the Dresden physicist, Heinrich Barkhausen, who accidentally heard them during World War I while *wire tapping* Allied field telephone conversations. The same inductive principles of "leakage" applied. Ignoring the normal atmospheric registers of "crackling or boiling noise" in the device, he would hear "a very remarkable whistling note," instead of military communications. Others heard it too. They compared it to the Doppler effect generated as "the grenades fly."[10] He expressed in letters as a diphthong *péou*. While he did not represent these sounds as musical, he did mention a

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[7] Watson, "The Earth, A Vast Orchestra," unpublished typescript, Boston: 1 October 1932, p. 1.

[8] Watson, "From Electrons to God: A New Conception of Life and the Universe," Boston: privately published, 1933, p. 3.

[9] See Douglas Kahn, "Ether Ore: Mining Vibrations in American Modernist Music," in: Veit Erlmann (ed.) *Hearing Cultures: Essays on Sound, Listening and Modernity*, Oxford: Berg Publishers, 2004, pp. 107-130.

"remarkable periodic process," which was the determinant in acoustical discourse at the time distinguishing music from noise.[11]

British engineer Eckersley, who was working at Marconi Wireless, wrote the second scientific paper on VLF: "A Note on Musical Atmospheric Disturbances" (1925). He too had been tutored in radio by World War I, working in service of the British Special Wireless Section stationed in Egypt and Salonika during World War I. He was assigned to direction-finding, or D/F, which entailed the use of specialized loop antennae to locate the source of enemy transmissions. He postulated that reflection downward from the Heaviside Layer, what would eventually be called the ionosphere, could be responsible for errors in determining the source of the signal; an understanding which improved intelligence in the area.[12] The Heaviside Layer had been theorized, but there was no compelling demonstration until the mid-1920s; whereas Eckersley wrote a report "sent to the War Office in 1916 [that] probably formed the first scientific discussion of this subject."[13] It was also his work that utilized and provoked musical discourse within the scientific study of these atmospheric *disturbances of a musical nature*.

"Music" was used for both descriptive and analytical purposes, and it was related experientially to onomatopoeia. Robert Helliwell of Stanford University wrote in his classic *Whistlers and Related Ionospheric Phenomena*:

> Much of the early work on whistlers was based on aural observations, with the result that a colorful onomatopoetic vocabulary was developed to describe different types of whistlers. With the development of whistler spectrology and theory, there has arisen a new nomenclature that reflects the spectrographic appearance of whistlers and the mechanism of whistler propagation.[14]

Onomatopoetic description was a blunt categorical instrument of tweeks, chinks, swishes, whistlers and *Pfeiftone*.[15] The practice was certainly generated at a vernacular level among

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10 Heinrich Barkhausen, "Zwei mit Hilfe der neuen Verstärker entdeckte Erscheinungen," *Physikalische Zeitschrift* 20 (1919), p. 401, as cited in his "Whistling Tones from the Earth, *Proceedings of the Institute of Radio Engineers* 18/7 (1930), pp. 1155-1159, quote on p. 1155.

11 Ibid., p. 1155. In 1919, Barkhausen knew the sounds were geophysically related, however, anything else was "inexplicable." By the time he revisited the topic in 1930, there was general knowledge of the reflective properties of the "Heaviside layer," especially with Appleton's experimental confirmation of the existence of the ionosphere, and he was able to conjecture that whistlers were related to the powerful electromagnetic impulse of lightning. His biggest problem remained in explaining the duration of the whistler since, if the Heaviside layer was reflecting at 100 km above the earth, and the signal was traveling at 300,000 km per second then a whistler lasting one second would require 1000 reflections. Even this figure he had to grant either "a greater altitude of the Heaviside layer or […] a lower propagation velocity" of the lower frequencies in the glissando of the whistler. But if this frenzied reflection held true generally, then other "atmospheric disturbances" would produce "tone character." (Ibid., p. 1157)

12 "The intelligence picture on the evacuation from Sinai and the redeployment of troops was also enhanced by D/F fixing and the familiarity gained by experienced operators with the electronic "signatures" left by their German and Ottoman counterparts." Yigal Sheffy, *British Military Intelligence in the Palestine Campaign, 1914-1918*, London: Frank Cass, 1998, p. 225.

13 John Ashworth Ratcliffe, "Thomas Lydwell Eckersley, 1886-1959," *Biographical Memoirs of Fellows of the Royal Society* 5 (February 1960), pp. 69-74, quote on p. 70.

14 Robert Helliwell, *Whistlers and Related Ionospheric Phenomena*, Stanford, CA: Stanford University Press, 1965, p. 83.

15 Thomas Lydwell Eckersley, "Musical Atmospherics," Supplement to *Nature* 135 (19 January 1935), pp. 104-105.

"workers in Radio," as Eckersley put it, and was subsequently standardized. For instance, the terms for general class of VLF included "*parasitics*, *statics, and X (strays),*" whereupon an agreement developed by the British Radio Research Board in 1921 sought replace them with the general term *atmospherics*; Eckersley himself still referred to "*musical strays*" in his 1925 paper.

Music was also used categorically, but more as a matter of degree, not only in keeping with the sliding tones and glissandi involved, but also with the admixture of the noises described onomatopoetically and the extent of tonal presence. E. T. Burton and E. M. Boardman, along with Barkhausen and Eckersley were the other main scientific contributors to the area. They classified "audio-frequency atmospherics" along a range of *musical and nonmusical.*[16] From recordings and oscilloscope readings made from both submarine cables and a long antenna, they discussed atmospherics that included *nonmusical* sounds such as "deep rumble intermittently broken by noises variously described as spashes and surges," *quasi musical* sounds of "hissing or frying," *slightly musical* sounds at higher frequency due to their *slightly tonal* character, and "two varieties of *distinct musical* atmospherics [...] given the names 'swish' and 'tweek.'"[17]

Onomatopoeia and music were afforded because VLF are in the human auditory range in the first place, and required because the science was being conducted prior to the use of sound or graphic recording. At the cusp, the 1933 researches of Burton and Boardman used magnetic recording which, in fact, were used for "sound spectrology" representations in the 1950s. In the 1930s, however, there was no way to communicate such recordings within the visual vernacular of scientific texts.

Music, nevertheless, was used as the tonal quotient of the auditory, in the descriptive degree in which it varied from *distinctly* onomatopoetic noises. The avant-garde character of the musical aesthetics involved comes from the non-resolute character in which sound and musical sound, or noise and music, are left in the functional terms of a gradient rather than the way it was commonly expressed elsewhere in scientific literature, where noise and music were separated between the poles of periodic and aperiodic waveforms.

This matter of degree was no doubt due to the primary objects of study, those being the sliding tones and glissandi (sliding tones writ large) of tweeks and whistlers. A glissando is not merely an object of study; it is also a dramatic exercise of the *tonal auditory*, especially since they were naturally occurring phenomenal realities from mysterious regions of the atmosphere and beyond. Such drama underscores the attempts to understand the transposition of wave functions from the old fields of music and acoustics to the new one of electromagnetics and radio science.

In terms of musical aesthetics, glissandi and sliding tones were championed from Ferrucio Busoni onward through the avant-garde as naturally occurring arguments against the strict separation of music and noise and against the fragmentation of tones into the notes of temperament. Indeed, the emphatic noise packet of the initial impulse of lightning, followed by silence, followed by a glissandi, would recapitulate the holy trinity of avant-garde musical aesthetics, and do so within the legitimating support of nature and the cosmos (or at least the above-it-all of the upper atmosphere).

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16 E. T. Burton and E. M. Boardman, "Audio-Frequency Atmospherics," *Proceedings of the Institute of Radio Engineers* 21/10 (1933), pp. 1476-1494.

17 Ibid., p. 1479.

The other aspect of the auditory, apart from the ability to observe and categorize these natural radio phenomena in the first place, was the ability for music, the musical discrimination of tones, to be used, in effect, as an analytical instrument, not just a means of description. Eckersley, in particular, used the dispersion of frequencies among atmospherics, a dispersion he knew from the tonal discrimination that is the glissando traversing the human audible range, as a means to understand the electron density of the upper atmosphere. This was a naturally occurring version to the "wireless methods [that] are perhaps the most effective in exploring this region."[18] Here he referred to Gregory Breit and Merle Antony Tuve, who used radio transmissions as a means for determining the height of the Heaviside Layer, and he no doubt had in mind the work of M. A. F. Barnett, Edward Victor Appleton and others using similar methods at the time.[19]

In contrast, and as a clear sign of the demise of the auditory after mid-century, there was a new type of whistler discovered by Helliwell and others in 1956 in the lead-up to the International Geophysical Year, where there was a slight delay in the upper frequencies due to "the earth's magnetic field along the path of propagation."[20] To the ear, it sounds as though the whistler is falling and rising at the same time in the upper register, but these whistlers are only heard with any regularity at higher latitudes, and even there they are fairly rare. At middle latitudes they occur, but the delay occurs at a higher frequency outside the human audible range. When the idealized features of this type of whistler were diagrammed, it generated its name: the nose whistler. Moreover, not only, as Helliwell stated, did "further study [show] that all ordinary whistlers were simply the lower-frequency parts of nose whistlers," it was also realized that when the delay frequency is known, "it is possible to calculate the distribution of electron density in the magnetosphere from roughly one earth radius to six earth radii," and to do so theoretically "from whistlers that do not show a nose."[21]

Noses and their absence can also generate other body parts, *pace* the rare *knee whistler*, a trace on the spectrograph showing "a nose [that] may actually cross a non-nose trace."[22] With no reference to a nose flute, the sensory passage has been made from the ear to the eye, the primary organ of electromagnetic phenomena. By the time Helliwell's standard text was published in 1965, in the once gradated musical domain of whistlers in Burton and Boardman, and the vernacular musical and onomatopoeic terms, the types now included one-hop, two-hop, hybrid, echo train, multi-component, multiple source, nose, and fractional hop. Other types of VLF included hiss, rising tone, falling tone, hook, dispersive, non-dispersive, multiphase, drifting, chorus, quasi-periodic emissions, and triggered emission.[23]

Following soon after the full demise of the auditory in the scientific literature, the composer Alvin Lucier heard a recording made by a Dartmouth College team of investigators, that had been circulating among hi-fi hobbyists since the mid-1950s, and began to introduce whistlers and atmospherics back toward the *poetic rapture of starry nights*. The poetics, however, could now take advantage of such things as knowing their source in lightning and the distances traveled around the earth and through the magnetosphere. He reveled in the fact that such energetic power and

18 Eckersley, "Electrical Constitution of the Upper Atmosphere," *Nature* 117 (12 June 1926), p. 821.
19 Eckersley, "The Constitution of the Heaviside Layer," *Nature* 117 (13 March 1926), pp. 380-381.
20 Helliwell, *Whistlers and Related Ionospheric Phenomena*, p. 20.
21 Ibid., p. 8.
22 Ibid., p. 133.
23 Ibid., p. 206.

monumental distance was required to produce such a delicately beautiful sound. A huge hydroelectric dam powering the tiny lilt of a shakuhachi would still not embody the magnitude involved. During the early-1990s, the Australian artist Joyce Hinterding began using sferics in a "visual arts" context; the compact disc releases of Stephen McGreevy reintroduced whistlers, auroral chorus and atmospherics to another generation; VLF began to be heard with some regularity among subcultural musicians and appearing in a range of artistic contexts. Presently, VLF is at the root of a general artistic and musical attention to electromagnetic phenomena, from the materiality of the signal to new spatiality of locative, mobile media and cyberspace.

Ästhetik des Signals

Daniel Gethmann

Dieser Vortrag handelt von zwei Radioempfangsexperimenten, die beide auf Langwelle beginnen und aus unterschiedlichen Perspektiven auf die konstitutive Position des Rauschens für die Kommunikation hinweisen. Ihnen gemeinsam ist, daß sie die Entstehung neuer Forschungsperspektiven markieren und auf unterschiedliche Weise aus der Schallforschung expandieren, indem sie ein störendes Rauschen zum Material eines neuen wissenschaftlichen Forschungsansatzes machen oder es auf seine Information hin untersuchen. Dabei geht es zunächst um folgende Frage: „Was sendet sich ganz von selbst, wenn kein Dämon dazwischentritt? Was kann man hören in einer Welt ohne Menschen? Die Turbulenz in ihrer Rohform, den Fluß der Teilchen, den Zusammenstoß der zufällig in der Zeit verteilten Individuen, das Strömen der Wolke aufgrund des Raumladungseffekts. Wer spricht im Innern dieser Wolke? Im strengen Sinne niemand, ganz gewiß aber das Objekt, die Sache selbst, die Welt. *Es* spricht, wie man sagt, aber hier behält die dritte Person jene klare Bedeutung, die sie niemals verloren hat: die Ansammlung von Objekten, die das Universum bilden; die Interobjektivität als solche.“[1]

Als Angehöriger der *Radio Research Division* der *Bell Telephone Laboratory* untersuchte der Ingenieur Karl Guthe Jansky zwischen 1928 und 1930 die Ursache der starken Interferenzen, die bei der Funktelephonie über lange Distanzen häufig auftraten.[2] Die *American Telephone & Telegraph Company* bot erstmals im Jahre 1927 einen öffentlichen funktelephonischen Dienst zwischen New York und London an, der auf der bereits zuvor als Kommunikationskanal für große Weiten ausgemachten Langwelle mit Wellenlängen von 5000 m (60 kHz) operierte. Jansky setzte auf einem größeren Farmgelände in Holmdell, New Jersey, mit dem Studium der Interferenzen auf Langwelle (‚recording long-wave static‘) auf der Frequenz an, wo das zweite Radioempfangsexperiment zuvor aufgehört hatte. Das häufige Auftreten dieser Interferenzen führte allerdings bereits im Jahre 1929 zur Umstellung des drahtlosen Gesprächsdienstes auf Kurzwelle zwischen 10-20 MHz, woraufhin sich Jansky dem Bau rotierender Antennen und dem Kurzwellenempfang (20,5 MHz) wegen der hier ebenfalls auftretenden Störungen zuwandte.

Bei seinen Empfangsexperimenten auf Kurzwelle ab dem Herbst 1930 machte Jansky starke Interferenzen aus, die er nahen und fernen Gewittern zuschrieb. Von ihnen ließ sich jedoch ein weiterer Typ des Rauschens unterscheiden: „a very steady hiss type static the origin of which is not yet known.“[3] Dessen akustische Performanz beschrieb Jansky so: „It is, however, very steady, causing a hiss in the phones that can hardly be distinguished from the hiss caused by set noise.“[4] Aus dem Vergleich seiner mehrjährigen Experimentaldaten entwickelte Jansky Ende des Jahres

1 Michel Serres, *Hermes II: Interferenz*, Berlin: Merve, 1992, S. 255.

2 Zu Jansky vgl. K. Kellermann und B. Sheets (Hg.), *Serendipitous Discoveries in Radio Astronomy*, Green Bank, West Virginia: National Radio Astronomy Observatory, 1983; Woodruff Turner Sullivan III, „Karl Jansky and the Discovery of Extraterrestrial Radio Waves“, in: ders., *The Early Years of Radio Astronomy: Reflections Fifty Years after Jansky's Discovery*, Cambridge: Cambridge University Press, 1984, S. 3-42.

3 Karl Guthe Jansky, „Directional Studies of Atmospherics at High Frequencies“, *Proceedings of the Institute of Radio Engineers* 20/12 (1932), S. 1920-1932, hier: S. 1925.

4 Jansky, „Directional Studies of Atmospherics at High Frequencies“, S. 1930.

1932 eine astronomische Erklärung für diese Interferenzen, d. h. er lokalisierte die Rauschquelle des *Radio Continuum* außerhalb unseres Sonnensystems („the direction of the phenomenon remains fixed in space“[5]) und mit dieser These wurde ‚cosmic static‘ zu einer Ressource astronomischer Erkenntnisbildung, die sich anhand der Suche nach weiteren ‚noiselike signals‘ aus dem All ausformte. Zunächst nahm die Fachwelt jedoch einen Vortrag von Jansky am 27. April 1933 auf der Jahrestagung der *International Scientific Radio Union* in Washington über: „Electrical Disturbances of Extraterrestrial Origin“ noch reaktionslos zur Kenntnis. Erst eine Pressemitteilung der *Bell Labs* und ein Artikel in der *New York Times* machten Jansky über Nacht so berühmt,[6] daß er in das *NBC Blue Radio Network* eingeladen wurde, wo seine Hörer am Abend des 15. Mai 1933 in einer Direktübertragung aus Holmdell, New Jersey, das Rauschen der Galaxie vernahmen – nach den Worten eines Hörers „sounding like steam escaping from a radiator.“[7]

Während die astronomische Fachwelt Janskys Empfangsexperimente vorerst ignorierte – die Astronomie der klassischen Observatorien verstand sich keineswegs als eine *Science of Sound* – beendeten Janskys Vorgesetzte in den *Bell Labs* seine Forschungstätigkeit zu „star noise“[8] genau zu dem Zeitpunkt, als er im August 1933 in einem internen Arbeitsbericht die Milchstraße als Quelle der ‚interstellar interference‘ bestimmt hatte.[9] Weder die Ungeheuerlichkeit dieser These, noch ihre Konsequenz, Kenntnisse des Universums aus dem Empfang elektromagnetischer Wellen abzuleiten und damit faktisch die Radioastronomie zu begründen, trug zur Einstellung weiterer Forschungstätigkeit bei; vielmehr genügte es im Sinne des Forschungsauftrags, den Rundfunkempfang zu verbessern, mit der Entdeckung von ‚star noise‘ vollkommen, was Jansky im Jahre 1937 im Abstract seines vorerst letzten Textes zu seinen Empfangsexperimenten notierte: „[O]n the shorter wave lenghts and in the absence of man-made interference, the usable signal strength is generally limited by noise of interstellar origin.“[10]

Das Rauschen also wurde während der Bestimmung seiner Quelle als definitiver Faktor in die Medienkommunikation eingeführt und ließ sich in ihren Modellen zur möglichst genauen Nachrichtenübertragung kalkulieren; Jansky, der ‚star noise‘ als konstante und grundsätzlich externe Geräuschquelle bestimmte, die eine Radio-Kommunikation limitiert, legte so die Voraussetzung dafür, das Rauschen als eine Konstante der Kommunikation – und keineswegs nur als ihre Störung – zu berechnen. Die Radioastronomie wiederum begann als Fehlersuche für drahtlose Telephonverbindungen in den *Bell Labs*, die sich ausschließlich auf die Verbesserung der irdischen Gesprächsqualität richtete und folgerichtig von der etablierten Astronomie nicht zur Kenntnis genommen wurde. Als Jansky im Oktober 1933 im *American Museum of Natural History* in New York wiederum über „Hearing Radio from the Stars“ sprach, zeigten sich seine Vorgesetzten in

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5 Jansky, „Electrical Disturbances Apparently of Extraterrestrial Origin“, *Proceedings of the Institute of Radio Engineers* 21/10 (1933), S. 1387-1398, hier: S. 1388.

6 Vgl. *New York Times*, 5. Mai 1933, S. 1.

7 Zit. nach Sullivan III, „Karl Jansky and the Discovery of Extraterrestrial Radio Waves“, S. 18.

8 Jansky in einem Brief an seinen Vater Cyril M. Jansky vom 29. 3. 1936, zit. nach Sullivan III, „Karl Jansky and the Discovery of Extraterrestrial Radio Waves“, S. 23.

9 Bereits in einem kurzen Artikel in *Nature* vom 8. Juli 1933 schrieb Jansky, „that the direction of arrival of this disturbance remains fixed in space, that is to say, the source of this noise is located in some region that is stationary with respect to the stars.“ (Jansky, „Radio Waves from Outside the Solar System“, *Nature* 132 (1933), S. 66.)

10 Jansky, „Minimum Noise Levels Obtained on Short-Wave Radio Receiving Systems“ (Summary), *Proceedings of the Institute of Radio Engineers* 25/12 (1937), S. 1517-1530, hier: S. 1517.

den *Bell Labs* bereits alles andere als begeistert von einer Fortsetzung seiner Forschungen. So schien ihm die einzige Möglichkeit darin zu bestehen, kommerzielle Radiosender zu einer Wiederholung der akustischen Radioastronomie-Experimente anzuregen. Dies gelang nicht, doch zumindest fand Jansky in einem enthusiastischen Radiobastler seinen für lange Jahre einzigen Nachfolger. Der Radioamateur Grote Reber verfolgte die Idee einer akustischen Radioastronomie hauptsächlich in seinem eigenen Garten, wo er eine Antenne errichtete und sich über den Zweiten Weltkrieg hinweg mit dem Empfang kosmischen Rauschens beschäftigte.[11]

Technische Vorrichtungen, die den Begriff der Kommunikation erneuern[12] und aus ihm eine der „bemerkenswertesten theoretischen Erfindungen“[13] des 20. Jahrhunderts machen sollten, brachten „wie für die Gesamtheit der Gedanken“ auf ihre Weise eindringlich zum Vorschein, daß „das Zufällige, das Hintergrundrauschen, *wesentliches* Moment der Kommunikation“[14] ist. Denn „das Rauschen gehört zur Kommunikation“,[15] deren Sender-Empfänger-Modelle bereits Jansky um diesen einen besonderen Faktor und seinen Ort erweitert hatte, der ein neues System hervorbrachte, eine Ordnung von höherer Komplexität, als die lineare Kommunikationsstrecke sie zuvor besaß. Anstatt am „Anfang einer neuen Ordnung“[16] das Janskys Forschungen motivierende, ingenieurstechnische Problem der ‚Communication in the Presence of Noise‘[17] – mit Shannon eine Optimierung der Verbindung innerhalb der linearen Sender-Empfänger-Strecke trotz allen Rauschens – zu verfolgen, indem man dieses auf den Kommunikationskanal reduziert, innerhalb dessen fortan Nachrichten „als Selektionen oder Filterungen eines Rauschens generierbar sind“,[18] soll hier die „experimentelle Verschaltung von Information und Rauschen“[19] aus der Perspektive ihres Mißlingens im Vordergrund stehen, als Zeichen sich noch aus dem Rauschen abhoben, statt selektiert zu werden. Um die Komplexität des neuen Systems zu verstehen, bedeutet das, vor seine Entstehung zurückzugehen und sich der Abweichung, der Unordnung und dem Rauschen als konstitutivem Element des Systems auf mehreren Ebenen

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11 Vgl. Grote Reber, „Early Radio Astronomy at Wheaton, Illinois“, *Proceedings of the Institute of Radio Engineers* 46/1 (1958), S. 15-23.

12 „The word communication will be used here in a very broad sense to include all of the procedures by which one mind may affect another. This, of course, involves not only written and oral speech, but also music, the pictorial arts, the theatre, the ballet, and in fact all human behavior. In some connections it may be desirable to use a still broader definition of communication, namely, one which would include the procedures by means of which one mechanism (say automatic equipment to track an airplane and to compute its probable future positions) affects another mechanism (say a guided missile chasing this airplane).“ (Warren Weaver, „Recent Contributions to the Mathematical Theory of Communication“, in: Claude E. Shannon und ders., *The Mathematical Theory of Communication*, Urbana: University of Illinois Press, 1949, S. 1-28, hier: S. 3).

13 Dirk Baecker, „Kommunikation“, in: Karlheinz Barck, Martin Fontius, Dieter Schlenstedt, Burkhart Steinwachs, Friedrich Wolfzettel (Hg.), *Ästhetische Grundbegriffe: Historisches Wörterbuch in sieben Bänden*, Bd. 3, Stuttgart/Weimar: Metzler, 2001, S. 384-426, hier: S. 384.

14 Serres, „Der platonische Dialog und die intersubjektive Genese der Abstraktion“, in: *Hermes I: Kommunikation*, Berlin: Merve, (1966) 1991, S. 49.

15 Serres, *Der Parasit*, Frankfurt am Main: Suhrkamp, 1981, S. 26.

16 Serres, *Der Parasit*, S. 121.

17 Shannon, „Communication in the Presence of Noise“ (1948), in: ders., *Collected Papers*, hg. von Neil J. A. Sloane und Aaron D. Wyner, New York: IEEE Press, 1993, S. 160-172.

18 Friedrich Kittler, „Signal-Rausch-Abstand“, in: Hans Ulrich Gumbrecht und K. Ludwig Pfeiffer (Hg.), *Materialität der Kommunikation*, Frankfurt am Main: Suhrkamp, 1988, S. 342-359, hier: S. 347.

19 Kittler, „Signal-Rausch-Abstand“, S. 345.

zuzuwenden sowie mit Michel Serres die Frage zu stellen, was aus ihm hervorgeht, was es also kommuniziert?

Die nach Janskys Theorem unvermeidliche Einbeziehung des Rauschens in jeden kommunikativen Akt innerhalb und außerhalb technischer Medien ergibt sich aus seinen Experimenten. Sie ergänzen einen Prozeß der Formalisierung, der sich innerhalb der Diskussion zur Informationsübertragung bereits im Jahre 1927 in der Forderung von Ralph Hartley artikuliert, jeden psychologischen Faktor aus den für eine Botschaft verwendeten Zeichen auszuschließen: „make each selection perfectly arbitrary".[20] Sobald feststeht, die Frage der Interpretation einer Nachricht zukünftig ignorieren zu können, ist es auch möglich, das Rauschen in die Übertragung einzuschließen,[21] in der so oberflächlich weiterhin das Paradigma ihrer Linearität zwischen zwei Punkten zum Tragen kommt, während doch notwendig auch mit einer dritten Rauschquelle gerechnet wird. Doch Janskys These erschöpft sich nicht in ihrem funktionalistischen Aspekt zur Optimierung der Informationsübertragung: „Gegeben sei ein schwarzes Ding, ein dunkler Vorgang, eine wirre Wolke von Signalen, also etwas, das man alsbald ein Problem nennen wird."[22] Es wird darin eine Ordnung höherer Komplexität als ein lineares bipolares Schema erkennbar, die unter dieser Perspektive impliziert, daß keineswegs geklärt ist, wer oder was dieses Problem darstellt, daß also das Rauschen ebenfalls Mitteilung sein wie zum Kanal gehören, aus ihm etwas hervorgehen kann, denn jede beliebige Position innerhalb dieser von Michel Serres entworfenen Triodenstruktur der Kommunikation ist potentiell als Problem oder als Mitteilung zu bestimmen.[23]

„Aus dem Hintergrundrauschen geht nichts hervor. Oder manchmal doch. Aber das ist eine andere Geschichte. Genau die Geschichte, die wir schreiben müssen."[24] Dazu notwendig ist ein Begriff mediengestützter Kommunikation, der nachvollzieht, daß deren spezifische kommunikative Inhalte und Formen nicht präexistent sind, sondern durch die Operationalität der verwendeten Medien überhaupt erst hervorgebracht werden.[25] Ein medialer Kommunikationsakt geschieht

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20 „The capacity of a system to transmit a particular sequence of symbols depends upon the possibility of distinguishing at the receiving end between the results of the various selections made at the sending end. [...] Hence in estimating the capacity of the physical system to transmit information we should ignore the question of interpretation, make each selection perfectly arbitrary, and base our result on the possibility of the receiver's distinguishing the result of selecting any one symbol from that of selecting any other. By this means the psychological factors and their variations are eliminated and it becomes possible to set up a definite quantitative measure of information based on physical considerations alone." (Ralph Vinton Lyon Hartley, „Transmission of Information", *The Bell System Technical Journal* 7 (Juli 1928), S. 535-563, hier: S. 537f.) Vgl. Friedrich-Wilhelm Hagemeyer, *Die Entstehung von Informationskonzepten in der Nachrichtentechnik: Eine Fallstudie zur Theoriebildung in der Technik in Industrie- und Kriegsforschung*, Diss., FU Berlin, 1979, S. 207-257.

21 „The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages." (Shannon, „The Mathematical Theory of Communication", in: ders. und Weaver, *The Mathematical Theory of Communication*, S. 29-125, hier: S. 31).

22 Serres, *Der Parasit*, S. 34.

23 Vgl. Serres, *Der Parasit*, S. 81-87 (Kapitel: „Diode, Triode").

24 Serres, *Hermes V: Die Nordwest-Passage*, Berlin: Merve, 1994, S. 45.

25 Vgl. für den Rundfunk: Daniel Gethmann, *Die Übertragung der Stimme: Vor- und Frühgeschichte des Sprechens im Radio*, Berlin/Zürich: diaphanes, 2006.

grundsätzlich nur auf der Grundlage von Signalen, die aus dem Rauschen hervorgehen, auf dessen Basis sich also Bedeutung, Zeichenlogiken und Sinn überhaupt erst abzeichnen. Läßt man das Rauschen nach Jansky nicht nur die verwendbare Signalstärke jeder Kommunikation limitieren, sondern mit Serres und Shannon als eigenen Kanal gelten, so dekonstruieren dessen Mitteilungen neben dem überkommenen Kommunikationsmodell auch die Referenz auf eine Idee, die als Objekt der Kommunikation seit John Locke von den für sie verwendeten Zeichen möglichst genau übertragen werden soll, da sie andernfalls semantisches Rauschen produziert.[26] Vielmehr ist es die Aufzeichnung der Signale selbst, die ihre Zeichen und in der Folge auch die Ideen überhaupt erst hervorbringt bzw. auf ihrer Folie konkretisiert.

Um diesen zentralen Punkt im Hinblick auf die Ästhetik im Experiment emblematisch zu veranschaulichen, lassen sich Signale analysieren, die aus dem Hintergrundrauschen hervorgegangen sind, deren Existenz sich ausschließlich den medialen Operationen selbst verdankt und die in Verfahren der Einschreibung auftreten.[27] Sie führen spezifische Formen der Signal-Zeichen-Differenz vor, wie sie seit den Lichtenberg-Figuren in technischen Medien exponiert wird. Seit dem Jahre 1777 ist es bekanntlich möglich, Medien (bei Georg Christoph Lichtenberg in der Form eines eigens gefertigten Harzkuchens) anzugeben, in denen etwas anderes vorgeht, als in allen Visualisierungsverfahren zuvor:[28] Ein physikalischer Träger eines Zeichens schreibt sich in sie als neue Ordnung des Signals ein. Deren Visualisierungsverfahren führt zu einem fundamentalen Bruch in der Seinsweise eines Zeichens, den Bernhard Siegert in seiner grundlegenden Studie zu den Zeichenpraktiken in der Neuzeit herausgearbeitet hat.[29] Die Bildung einer neuen Ordnung des Signals läuft nun der Entwicklung moderner technischer Medien voraus, sie tritt in ihnen in ständig verwandelter Form immer wieder neu auf. Die Signal-Zeichen-Differenz kommt als Ausgangspunkt der in und mit den Medien geschehenden Kommunikation, deren nachrichtentechnische Aspekte sich mit ihren semiotischen durchaus überschneiden,[30] insbesondere dann zum Vorschein, wenn sie mißachtet oder übersehen wird und in der Folge semantisches oder ideographisches Rauschen produziert. Der Bruch in der Ordnung der Zeichen tritt gerade in Phasen des Medienwandels ans Licht, wenn medientechnische Innovationen die Kommunikationsbedingungen und ihre Kanäle so stark erschüttern, daß sogar die grundsätzliche Unterscheidung in Frage steht, ob es sich bei den drahtlos

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[26] „Wenn die Wörter dem Zweck der Mitteilung dienen sollen, so ist es, wie bereits gesagt, notwendig, daß sie beim Hörer genau dieselbe Idee hervorrufen, für die sie im Geiste des Redenden stehen. Andernfalls füllen sich die Menschen gegenseitig die Köpfe mit Geräuschen und Tönen, ohne sich dadurch ihre Gedanken zu vermitteln und einander ihre Ideen darzulegen, worin jedoch der Zweck der Unterhaltung und der Sprache besteht." (John Locke, *Versuch über den menschlichen Verstand* (1690), Bd. 2, 3. Buch, Kapitel IX.6, Hamburg: Meiner, 1988, S. 103).

[27] Der Übergang zu Verfahren der Einschreibung in der Radioastronomie geschieht nach Gerrit Verschuur zwecks Konstitution von Bedeutung im Auge des Betrachters: „listening to the noise from space is of little practical value. The cosmic radio signals need to be translated into electrical currents which are then used to drive a moving pen over a paper chart or converted into numbers to be handled by a computer for later study [...] and displayed in a way which means something to the human eye." (Gerrit L. Verschuur, *The Invisible Universe Revealed: The Story of Radio Astronomy*, New York: Springer, 1987, S. 77).

[28] Vgl. ausführlicher: Gethmann, „Innere Scheinbilder: Von der Ästhetik der Elektrizität zur Bild-Konzeption der Erkenntnis", in: Rolf Nohr, *„Evidenz - ... das sieht man doch!"* Münster: LIT, 2004, S. 125-161.

[29] Vgl. Bernhard Siegert, *Passage des Digitalen: Zeichenpraktiken der neuzeitlichen Wissenschaften 1500-1900*, Berlin: Brinkmann & Bose, 2003.

empfangenen Informationen um Bilder oder Töne, um das Zufallsrauschen des Hintergrundes oder doch um Signale oder gar Zeichen handelt. Dabei bildet sich eine Materialität des Signals ab, die als Vorbedingung medialer Kommunikation über ihre Formen und Inhalte entscheidet und deren Abbildung damit auch die anschließende Frage nach der Referenz ihrer Zeichen neu stellt.

Der amerikanische Filmpionier Charles Francis Jenkins ließ am 24. November 1894 einen von Edisons Kinetoskop inspirierten Projektor, das ‚Phantoscope', patentieren und entwickelte zudem eine ‚kinetographic camera' mit vier synchron mit dem Filmtransport rotierenden Linsen.[31] Im Jahre 1916 gründete er die *Society of Motion Picture Engineers* und wurde auch ihr erster Präsident. Als kreativer Erfinder, der mehr als 400 Patente auf den Gebieten der Kinematographie, der Automobiltechnik und des Flugzeugbaus beantragte, gilt Jenkins ebenfalls als ein Pionier des mechanischen Abtast-Fernsehens in den USA, dessen Entwicklung er wie sein 21 Jahre jüngerer Gegenspieler John Logie Baird aus Großbritannien entschieden vorantrieb. Sein erster utopischer Vorschlag für elektromagnetisches Fernsehen geht auf das Jahr 1913 zurück; dabei beabsichtigte Jenkins, das Prinzip der Selenzelle in die Fläche einer ganzen lichtempfindlichen Platte zu übertragen, deren elektrische Impulse dann drahtlos an eine weitere Platte gesendet werden sollten: „the plate would glow with varying intensity in different parts of the plate represented by the picture. This is somewhat analogous to the localized magnetic field which Prof. Poulsen employs to record and reproduce sound on a steel disc. [...] It will thus be seen that this thorium plate glows with a surface intensity corresponding to the picture at the distant station."[32]

Auf dem Gebiet der Bildübertragung war Jenkins bereits langjährig tätig, als er am 3. Oktober 1922 sein Verfahren zur telegraphischen und später auch zur drahtlosen Photoübermittlung[33] öffentlich vorführte.[34] Es basierte auf zwei rotierenden, prismatischen Ringen, die ursprünglich an einem Filmprojektor die Flügelblende ersetzten, den Lichtstrahl kontinuierlich brachen und an

30 Das sich auf der Folie des Rauschens abzeichnende signaltechnische Problem, wie genau „die Zeichen der Kommunikation übertragen werden" können, bestimmte Weaver im Jahre 1949 als die zentrale Ebene der Kommunikation, die auf das semantische Problem der Übereinstimmung von verwendetem Zeichen und erwünschter Bedeutung sowie auf das Effektivitätsproblem der Nachricht in einem signifikanten Maße wirke, so daß eine Analyse der technischen Probleme „eine stärkere Überlappung dieser Ebene mit den anderen beiden offenbart" als man für gewöhnlich annähme. Daher sei eine Analyse der technischen Probleme „in einem bedeutsamen Grad auch eine Theorie der [anderen beiden] Ebenen." (Weaver, „Ein aktueller Beitrag zur mathematischen Theorie der Kommunikation", in: Shannon und ders., *Mathematische Grundlagen der Informationstheorie* (1949), übers. von Helmut Dressler, München/Wien: Oldenbourg, 1976, S. 11-39, hier: S. 12ff.)

31 Vgl. Charles Francis Jenkins, *Animated Pictures*, New York: Arno Press & The New York Times, 1970 (Nachdruck der Ausgabe Washington, DC 1898), S. 25-42 (Kapitel: „The Phantoscope"); Laurent Mannoni, *The Great Art of Light and Shadow: Archaeology of the Cinema*, Exeter: University of Exeter Press, 2000, S. 429-432.

32 Jenkins, „Motion Pictures by Wireless", in: *Motion Picture News* 8/14 (1913), S. 17-18, hier: S. 18.

33 Den ersten Vorschlag hierzu machte Jenkins bereits im Jahre 1894 als ‚theoretical device' auf der Basis von Selenzellen: Zahlreiche selenhaltige Drähte, die das Kamerabild als loops geschaltet abtasteten, wurden einzeln zum Bild-Empfänger geleitet, wo sie Glühfäden in unterschiedlicher Intensität zum Leuchten brachten. (Vgl. Jenkins, „Transmitting Pictures by Electricity", *Electrical Engineer* 18/325 (1894), S. 62f.)

34 Vgl. Albert Abramson, *The History of Television, 1880 to 1941*, Jefferson, NC: McFarland, 1987, S. 53; David E. Fisher und Marshall Jon Fisher, *Tube: The Invention of Television*, San Diego u.a.: Harcourt Brace, 1997, S. 43f.; Russell W. Burns, *Television: An International History of the Formative Years*, London: Institute of Electrical Engineers, 1998, S. 195-205.

eine Photozelle sandten. Am 2. März 1923 wurde erstmals ein spezielles ‚Radio-Photo'[35] von der US-Navy Radio Station NOF in Washington zum *Evening Bulletin* nach Philadelphia verschickt und von der Zeitschrift abgedruckt.[36] Die Bildübertragung verblieb mit ihren wenigen Zeilen in einer Logik der Schrift, eine ‚Jenkins Picture-Strip Machine' wurde von ihm sogar eigens zur Schriftübertragung entwickelt. Mit ihr konnte ein langer Bericht nach dem gleichen Prinzip mit einer Photozelle in eine elektrische Signalfolge umgewandelt und über Radio verschickt werden, während beim Empfang Photopapier oder Filmstreifen über einen rotierenden Zylinder gezogen wurden, in dem die Lichtquelle Zeile für Zeile die Signalfolge erneut einschrieb.[37]

„C. Francis Jenkins, who has been a prominent experimenter in the field of transmitting photographs by radio, set up a machine designed to receive on a moving film any message that might come smashing through the ether."[38] Dementsprechend gehörten Jenkins Apparaturen im August 1924 zur Experimentalanordnung bei einem Radioempfangsversuch, bei dem über 30 leistungsstarke Armee- und Marinefunkstationen der US-Streitkräfte den Auftrag erhielten, gemeinsam mit Wissenschaftlern in den USA und Europa sowie zahllosen Radioamateuren in den Weltraum zu lauschen.[39] Darauf Bezug nehmend erschien am 21. August des Jahres 1924, als sich zwei Tage später die Planetenbahnen von Erde und Mars in einer sogenannten Perihelopposition befanden und damit eine so große Annäherung wie seit achtzig Jahren nicht mehr aufwiesen, in der *Washington Post* die Schlagzeile: „Army Radio Force to Listen For Signals From Martians."[40] Die US-Streitkräfte versprachen, „to ‚pick up' any unusual radio phenomena [...] and to note strange signals in their logbooks".[41] Von ihrer Mitwirkung an diesem Experiment hatte sie dessen Initiator, der ehemalige Leiter des Astronomie-Instituts am Amhearst College und des dortigen Observatoriums, David Todd, überzeugt. Seine Konzeption verband grundlegende astronomische Kenntnisse der Berechnung von Planetenbahnen mit der kommunikationseuphorischen Annahme, daraus den richtigen Zeitpunkt entnehmen zu können, um elektromagnetische Signale vom Mars zu empfangen. Er kündigte daher im gleichen Zeitungsartikel den Einsatz eines

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35 Jenkins trennte sprachlich präzise zwischen Medien, die an Kabel gebunden waren und den neuen drahtlosen Radio-Übertragungstechniken: „In our laboratory we have found it convenient and informative to use the words radiogram, radiophone, and radio vision when we speak of radio-carried service; and to say telegram, telephone, or television when we speak of wire-carried service." (Jenkins, „Radio Vision", *Proceedings of the Institute of Radio Engineers* 15, November (1927), S. 958).

36 Vgl. *Evening Bulletin*, 3. März 1923; *Washington Star*, 3. März 1923; Jenkins, *Vision by Radio – Radio Photographs – Radio Photograms*, Washington, DC: Jenkins Laboratories, 1925, S. 119.

37 „In the sending machine the rotating prisms sweep the image of the typewriter line across the light sensitive cell; and the strip is moved longitudinally by winding on a drum. In the receiving machine the strip is drawn along while it is curved around a rotating cylinder inside which the modulating light is located, turned off and on by radio. A corona glow lamp is preferably employed with the photographic paper." (Jenkins, *Vision by Radio*, S. 103).

38 *New York Times*, 23. August 1924, S. 9.

39 „Powerful radio stations of both the Army and Navy Departments will stand by from midnight tonight to 8 a.m. Monday to ‚listen in' for possible signals from Mars. Admiral Eberlen, Chief of Naval Operations, issued orders tonight to naval stations, including those in Honolulu, Balboa, Canal Zone; San Juan, Sitka, Alaska and Cavite, Philippine Islands. A similar order was issued to army stations earlier in the day by the War Department." (Anonym, „Listening for Mars. Heard Anything?" *New York Times*, 22. August 1924, S. 13).

40 Anonym, „Army Radio Force to Listen For Signals From Martians", *Washington Post*, 21. August 1924, S. 9; die *New York Times* schrieb: „to ‚listen-in' for any signals which the radio experts of Mars might attempt to make." (Anonym, „Asks Air Silence When Mars is Near", *New York Times*, 21. August 1924, S. 11.)

41 Anonym, „Army Radio Force to Listen For Signals From Martians", S. 9.

Aufnahmegeräts im Labor von Charles Francis Jenkins an: „Dr. Todd asserted, an automatic recorder, with slow-reeling tape, will be put in operation in the laboratory of the inventor, C. Francis Jenkins, at 1519 Connecticut avenue northwest. This recorder, he said, will be set to run 100 hours and will pick up any unusual radio signals.“[42] Um die Apparatur in Jenkins Washingtoner Werkstatt in geeigneter Weise einzusetzen, kämpfte Todd für seine Idee eines *National Radio Silence Days*, wie er später pathetisch genannt wurde, also für eine fünfminütige Sendepause aller nationalen US-Rundfunksender in jeder vollen Stunde während der anderthalb Tage der größten Annährung an den Planeten Mars. Sowohl mit zahlreichen Botschaften, dem Leiter der militärischen Stationen des US-Signalcorps, Charles M. Saltzman, der US-Navy als auch mit den Präsidenten der *Radio Corporation of America* und der *National Association of Broadcasters* traf er entsprechende Vereinbarungen.[43]

Erste Berichte über „Queer Sounds in Vancouver“ wurden bereits am 21. August 1924 von dort gemeldet: „Mysterious signals picked up at Point Grey Wireless Station here during the last week culminated today in a strange group of sounds, causing wireless experts here to wonder if the planet Mars is trying to establish communication with the earth. Four distinct groups of four dashes each came through the ether today, the operator stated. The signals were in no known code, starting on a low note and ending with a ‚zipp‘, and neither a spark nor a continuous wave is responsible for the sounds.“[44] Wie sich herausstellte, waren die Signale bereits seit einem Monat von kanadischen Radiotechnikern in Point Grey empfangen worden: „The sounds had not been considered seriously by the operators until last day or two,“[45] als eine neue Kontextualisierung durch den Marstransit und das Radioempfangsexperiment stattfand. Der Aufgabe einer von Hartley drei Jahre später in seinem Text zur ‚Transmission of Information‘ dezidiert ausgeschlossenen Signalinterpretation stellten sich auch britische Wissenschaftler und Experten der *Marconi Company* laut eines Berichts der *New York Times* mit der Schlagzeile: „Radio Hears Things As Mars Nears Us“ bei einem Empfangsexperiment in London: „Tuning in started at 12:30 a.m., and at 1 a.m., on a 30,000-meter radius, sounds were heard which could not be identified as coming from any earthly station. The sounds were likened to harsh dots, but they could not be interpreted as any known code. The noises continued on and off for three minutes in groups of four and five dots.“[46] In den Washingtoner Aufzeichnungen von ‚Jenkins Picture-Strip Machine‘ fand sich neben solchen regelmäßigen Signalfolgen jedoch auch die eigentliche Sensation des Empfangsexperiments: „The film, thirty feet long and six inches wide, discloses in black on white a fairly regular arrangement of dots and dashes along one side, but on the other side at almost evenly spaced intervals are curiously jumbled groups each taking the form of a crudely drawn face.“[47] Die folgende ekstatische Bildbetrachtung nahm das Signal fürs Zeichen: Die Auf-

42 Anonym, „Army Radio Force to Listen For Signals From Martians“, S. 9.

43 „Professor David Todd, former head of the Astronomy Department at Amherst, obtained informal assurances from the Army and Navy departments today that his request for silence in the air would be observed as far as possible during the period next Friday and Saturday when Mars will be nearest the earth. Professor Todd has announced that he intends to try to communicate with Mars. Willingness to cooperate was manifested by other Government departments.“ (Anonym, „Asks Air Silence When Mars is Near“, S. 11.)

44 Anonym, „Radio Hears Things As Mars Nears Us: A 24-Tube Set in England Picks Up Strong Signals Made in Harsh Dots“, *New York Times*, 23. August 1924, S. 1.

45 Anonym, „Radio Hears Things As Mars Nears Us“, S. 1.

46 Anonym, „Radio Hears Things As Mars Nears Us“, S. 1.

zeichnungen von Jenkins Apparatur schienen eine ‚Radio-Vision' zu enthalten, die auch als verrauschtes Portrait aus dem All angesehen werden konnte.

Indem die Vorrichtung Signale aufzeichnete und sie auf einem Filmstreifen abbildete, koppelte sie das Konzept vom Seleniten – eine Idee von Lebewesen auf dem Mond aus dem 17. Jahrhundert – an ihre Signalschrift. Als Folge dieser Kopplung wurde die utopische Vorstellung vom Seleniten von ihrem zwölften Platz auf einer Liste von „allerley wunderbahren Menschen"[48] aus direkt ins Zeitalter technischer Medien katapultiert, dabei in einer materiellen Form realisiert und sogar als konkreter Kommunikationspartner instituiert, der über ein gewisses Maß an (radio)technischer Vorbildung und Intelligenz verfügte sowie vor allem präsent wurde. Aus dem „Rauschen des Schriftzugs"[49] ging eine Ästhetik des Signals hervor, die kommunikationseuphorisch das elektromagnetische Signal für das Zeichen und das Zeichen für das Bild hielt, wodurch sich das Bezeichnete, eine Vorstellung vom Seleniten, in dem Moment des Radioempfangsexperiments medial konkretisierte, als sein vermeintlicher Kommunikationswert zum Vorschein kam. Infolgedessen wandelte ‚la face signifiante' in der Wahrnehmung von Jenkins Signalfilm ‚la face signifiée' zu einer zentralen Medienfigur des 20. Jahrhunderts, denn das Spiel von Differenzen zwischen Signal, Zeichen und Abbild schien in einer Innerlichkeit der Einschreibung aufzugehen, in der schließlich das Bezeichnete selbst durch seine mediale Sichtbarmachung neu erfunden wurde. Erst die Operation des Signals brachte demnach ihren (Ab-)Sender überhaupt hervor, realisierte ihn aus einer Liste imaginärer Kommunikanten als Gesprächspartner und gab ihm aus der Signalaufzeichnung seiner vermeintlichen Mitteilung auch gleich sein Gesicht.

Das Radio-Experiment vom August 1924 war hauptsächlich auf den Empfang von Wellenlängen zwischen 5000 und 6000 m, also auf Langwelle ausgerichtet, deren Frequenzbereich sich terrestrisch als Bodenwelle ausbreitet und der Erdkrümmung folgt. Diese Erklärung wurde erst später dafür angegeben, daß der Versuch schon aus technischen Gründen dazu verurteilt war, zunächst akustisches und mit Jenkins Vorrichtung auch ideographisches Rauschen zu produzieren. „‚I don't think the results have anything to do with Mars,' says Mr. Jenkins. ‚Quite likely the sounds recorded are the result of heterodyning or interference of radio signals. The film shows a repetition, at intervals of about a half hour, of what appears to be a man's face. It's a freak which we can't explain.'"[50] So folgte dem bangen Erschauern, was sich wohl aus dem Hinter-

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[47] Anonym, „Seeks Signs From Mars In 30-Foot Radio Film", *New York Times*, 28. August 1924, S. 6; „The development of a photographic film record of radio signals during a period of about twenty-nine hours, while Mars was closest to earth, has deepened the mystery of the dots and dashes reported heard at the same time by widely separated operators of powerful stations." (Ebd.)

[48] Johannes Praetorius, *Anthropodemus Plutonicus, das ist eine neue Welt-Beschreibung von allerley wunderbahren Menschen, als da seyn die 1. Alpmännergen, Schröteln, Nachtmähren. 2. Bergmännerlein, Wichtelin, Unter-Irrdische. 3. Chymische Menschen, Wettermännlein. 4. Drachenkinder, Elben. 5. Erbildete Menschen, Seulleute. 6. Feuermänner, Irrwische, Tückebolde. 7. Gestorbene Leute, Wütendes Heer. 8. Haußmänner, Kobolde, Gütgen. 9. Indianische Abentheur. 10. Kielkröpfe, Wechselbälge. 11. Luftleute, Windmenschen. 12. Mondleute, Seleniten. 13. Nixen, Syrenen. 14. Oceänische oder Seemänner. 15. Pflantzleute, Alraunen. 16. Qual- oder Verdammte-Menschen. 17. Riesen, Hünen. 18. Steinmänner. 19. Thierleute, Bestialische, Weerwölfe. 20. Verwünschte Leute. 21. Waldmänner, Satyren. 22. Zwerge, Dymeken,* Magdeburg: Lüderwald, 1668-1677; der Astronom Johannes Hevelius (1611-1687) hatte in seiner *Selenographia sive lunae descriptio* aus dem Jahre 1647 bereits Seleniten als Lebewesen auf dem Mond beschrieben.

[49] Serres, „Der platonische Dialog und die intersubjektive Genese der Abstraktion", S. 49.

[50] Anonym, „Seeks Signs From Mars In 30-Foot Radio Film", S. 6.

grundrauschen als Gestalt zu erkennen gäbe, umgehend die Ernüchterung. Ihr war bereits die Enttäuschung über das Schweigen des Planeten vorausgegangen, was sich am Tag nach dem *National Radio Silence Day* in der Schlagzeile ausdrückte: „Mars Sails By Us Without A Word: No Message Comes From Planet, Ruddily Glowing as it Nears the Earth."[51] Auch die euphorischen Meldungen der letzten Tage wurden umgehend wieder dementiert: „Strange Signals Not From Mars"; sowohl die in London empfangenen Signale erschienen als eine Mischung aus atmosphärischer Elektrizität und Interferenzen zwischen einzelnen Stationen[52] wie auch die in Vancouver eingegangenen Signale wurden als irdisches Radio-Signalfeuer identifiziert.

Artikulierte sich im Radioempfangsexperiment des Astronomen Todd im Jahre 1924 eine Präsenz, die erst angesichts einer Aufzeichnung von Störungen und Interferenzen ihre Entstehung erlebte, so entdeckte der Radioingenieur Jansky ab dem Jahre 1930 in seinen Experimenten, die sich auf eine Analyse der Störungen und Interferenzen des Radioempfangs richteten, im Empfang von ‚cosmic static' eine neue Methode astronomischer Erkenntnisbildung. Somit transformiert die Ordnung elektromagnetischer Signale nicht nur die Methoden astronomischer Wissensproduktion, sondern sie weist auch darauf hin, in welchem Maße eine Theorie medialer Zeichen im 20. Jahrhundert nachrichtentechnischen Aspekten untersteht. Denn hinter dem ursprünglichen *signatum*, das für die Konstruktion von Bedeutung unverzichtbar scheint, wird eine ganze Ökonomie von medialen Zeichenoberflächen sichtbar, die Bedeutung hervorbringen, aus der dann – in einem zweiten Schritt – jede Medienkommunikation auch ihre sozial bestimmte Referenz entwickelt. Eine Ästhetik des Signals eröffnet eine spezielle Perspektive auf die Grundlagen dieser Medienkommunikation: Im Radioempfangsexperiment vom August 1924 geben sich im Rauschen der Signalschrift die technischen Bedingungen medialer Präsenzeffekte flüchtig zu erkennen, indem die grundlegende Differenz zwischen der Übertragung von Signalen und den medialen Zeichenoberflächen nicht mehr in dem Maße ausgeblendet wird, wie sie die Medien für gewöhnlich als das verbergen, was ihre Operationen erst ermöglicht. Die Störung und ihre Schrift bringen vielmehr eine Gestalt zum Vorschein, die direkt aus dem Rauschen hervorgeht, das nach Serres die Figur des Dritten in der Kommunikation bildet: „Diesen Dritten haben wir an anderer Stelle den *Dämon* genannt, das personifizierte Rauschen."[53] Ihm auf die Spur gekommen zu sein, stellt sich als ein Unfall dar, dessen Aufzeichnungen das Gesicht des Rauschens überliefert haben.

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51 *New York Times*, 24. August 1924, S. 30.

52 „The object was to hear any signals that might be coming from Mars. As might have been expected, no such signals were received; but American broadcasting was heard on a small loop." (*Scientific American* 131 (November 1924), S. 336).

53 Serres, „Der platonische Dialog und die intersubjektive Genese der Abstraktion", S. 50.

Producing, Representing, Constructing: Towards a Media-Aesthetic Theory of Action Related to Categories of Experimental Methods

Elena Ungeheuer

Abstract:

Our subject is art meeting science, not on the level of common subjects or in the constellation of master (art) and assistant (science), but on the level of common methods. Producing, representing, and constructing are categories of scientific experiments formulated by Michael Heidelberger. We can use those categories to classify experimental doing in music as well. Thus, we build up an aesthetical theory of action which constitutes a crucial instrument for a pragmatic reading of media-aesthetic concerns.

Science and Art in the History of Electronic Music

In the early history of electronic music, developed in the broadcast studios of the 1950s, composers and technicians appreciated scientific advice, as they searched for answers to questions like these: How can timbre be composed? What are the characteristics of noise? What is a formant? Between 1949 and his early death in 1959, Werner Meyer-Eppler, acoustician and phonetician at the University of Bonn, worked in support of composers, presenting lectures, leading discussions, and writing letters and publications. He was qualified first as professor in the discipline of experimental physics with his main focus on acoustics. His second *Habilitation*, after World War II, was dedicated to phonetics; he always moved between science and humanities. Meyer-Eppler was one of the few scientists who integrated his research in the field of communication theory and technology into the context of art.[1]

Concerning Meyer-Eppler's experiments, there is more than one observation to be made. Meyer-Eppler seemed to feel almost a spark of inspiration within him of where to start an experiment. Hugo Dingler, the famous physicist, argued in his treatise about the character of the experiment that intuition might play the role of a trigger for experimental doing even in the context of serious physics. Dingler said:

> The final goal of theoretical physics as an ancillary science is always the advancement of experimental physics. The former hopes to smoothly integrate the measured results of the latter where holes remain, in order to prompt new experiments. In this way it is clear that the process, when all is said and done, is conditional upon the psychology of the experimental physicist. He is the one who will find something new in reality, something new that expands the mastery of humankind over nature, who will open new possibilities for us. The 'finding' of something new, however, will by no means always be handled through rational circumstances. Very often associations from accustomed, but perhaps theoretically accessible, paths are more useful to the practical researcher than truly new ways of thought. If our experimental physicists have accustomed themselves to the kind of theoretical physics described above and are able to find something new along these paths, then the method is at

1 The estate of Werner Meyer-Eppler is held in the Archiv der Akademie der Künste, Berlin.

> least justifiable as long as even the experimental physicists can not proceed through another method of thought.[2]

Dingler's perspective points in two directions:

1. Proposing that the ideal experiment can be deduced from theory, Dingler formulated an underlying hierarchy that placed experimental acts on the first level and theoretical acts on the second level. He even recognised theoretical physics as being an ancillary science of experimental physics.
2. Dingler referred to 'accustomed ways' of thinking in opposition to 'rational' ways of finding something new in the physical world. There is a sort of habit to be observed in the way Meyer-Eppler circled around the focus of his investigations, producing plenty of similar, but not identical, experiments before coming to the right formulation of the problem. Thinking seems to be directly related to acting.

The characteristic traits of Meyer-Eppler's experiments – his numerous studies comparing, contrasting, interweaving, and continuously transcending music and speech – often refer to aspects or potentialities of an apparatus. This has to be kept in mind when we try to analyse the scientific and artistic works of that time. In concrete words: Without having stood in front of a table tape recorder equipped to function at a speed of 38.1 cm/second and 76.2 cm/second, one won't ever understand how experimental acoustics and phonetics and their relationships to aesthetic contexts could develop in such a fruitful way in the 1950s. This observation shouldn't lead to a simple proposition of causality: 'First the techniques, than the ideas.' Instead, the role of the manual dimension comes into the fore, when we try to recapitulate how machines could be treated, how they were treated, and which manipulations could be done to them even against their inherent functionality.

There are different reasons why a phonetician could become so important for the development of music. One lies in the historical interdependency of speech research and music research. Hermann von Helmholtz's principle of generating vowels from his research into speech was used by Friedrich Trautwein in the 1920s to design a musical instrument, the trautonium. There was just one generator provided to generate all tones: a glow discharge tube (*Glimmentladungsröhre*). His saw wave offered enough partials to filter every wanted tone. In addition to the speech research by Helmholtz, Carl Stumpf, and Ludimar Hermann, the work done by acoustician Karl Willy Wagner, director of the Heinrich-Hertz-Institut für Schwingungsforschung in Berlin, became important. Wagner modelled synthetic generation of

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2 "Das letzte Ziel der theoretischen Physik als einer Hilfswissenschaft ist immer die Förderung der experimentellen Physik. Sie will die Messungsresultate der letzteren einheitlich zusammenfassen, wo sich noch Lücken befinden, um zu neuen experimentellen Untersuchungen anregen. So ist es klar, daß ihr Verfahren in seinem letzten Ende bedingt ist durch die Psychologie des experimentellen Physikers. Dieser ist derjenige, der in der Realität Neues finden soll, Neues, das die Naturbeherrschung der Menschheit erweitert, neue Möglichkeiten uns eröffnet. Das 'Finden' von Neuem wird aber keineswegs immer durch rationale Umstände beherrscht, sehr häufig sind dem praktischen Forscher Assoziationen in gewohnten, aber vielleicht theoretisch angreifbaren Bahnen nützlicher als noch so richtige neue Denkwege. Haben sich unsere experimentellen Physiker also an die oben geschilderte Art der theoretischen Physik gewöhnt, und vermögen sie auf diesen Bahnen Neues zu finden, so ist damit schon diese Art wenigstens solange gerechtfertigt, als eben die experimentellen Physiker nicht mit einer anderen Denkart vorwärts kommen." Hugo Dingler, *Das Experiment: Sein Wesen und seine Geschichte*, Munich: Reinhardt, 1928, p. 34-35.

timbres by filter processes. Trautwein's patent from 1924 was dedicated to the construction of the device and was titled *Verfahren zur Erzeugung musikalischer Töne bestimmter Klangfarbe*.[3] Wagner for his part was not interested in designing musical instruments. He had noticed Trautwein's experiments in electronic impulse excitation of formants and prepared a project concerning synthetic vowels for the Akademie der Wissenschaften. He wanted to design a new electric speech instrument. Moving from Berlin to the Bell Laboratories in New York, Wagner expanded his approach to the new technology of speech synthesis. In 1939, Homer Dudley and colleagues invented the voder (Voice Operation Demonstrator). Every formant filter was triggered by a specific key. The spectral vocoder that was developed later had a dual nature. On the coding side, the original speech signal was divided into characteristic frequency channels. On the decoding side, the resulting tensions controlled an impulse generator for generating vowels and a noise generator for generating consonants.

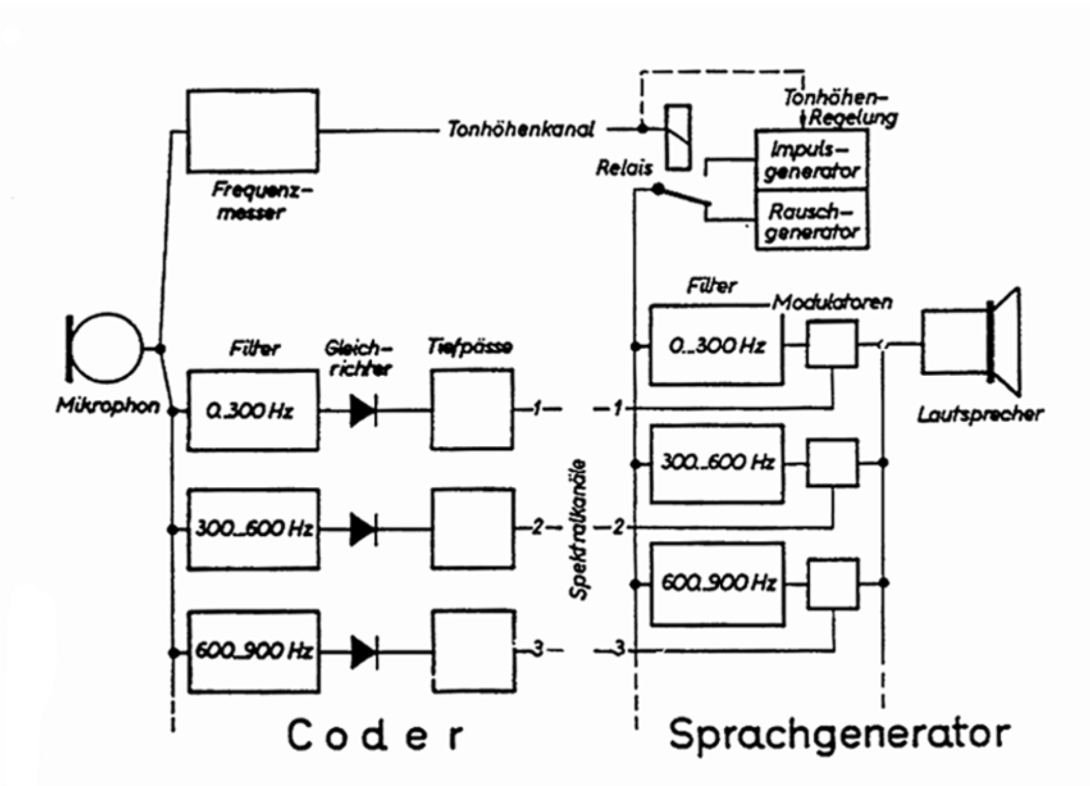

Fig. 1: This scheme of a vocoder was presented by Werner Meyer-Eppler in his lectures.

Meyer-Eppler, who in the late 1940s was engaged in transferring American acoustical research to Germany, which had been bled of its scientists, presented the vocoder at the first *Tonmeistertagung* in Detmold in September 1949. He showed this scheme and played sounds that demonstrated how each parameter of voice could be easily transformed by the vocoder: intervals were transversed, tremolo effects were added, one voice was multiplied, frequency was shifted. The vocoder seemed to be the perfect instrument for theatre voice management. In terms of the relationship between

3 Patent number 469775, 4 April 1924.

science and art, this demonstration at Detmold was the beginning of a new era of electronic music. Robert Beyer, *tonmeister* at the NWDR broadcasting in Cologne, assisted with Meyer-Eppler's lecture and perceived something very exciting in the examples. It was the manipulative impact on sound, the entering into the inner structure of sound that impressed him and gave him the idea that the time had come in which his dreams of a new world of music, dreams that had obsessed him as early as 1928, could be realised. Beyer appointed Meyer-Eppler as scientific advisor for the installation of a studio for electronic music in the broadcasting station of Cologne, connecting him with the director Hanns Hartmann and Herbert Eimert, the man responsible for the program.

Fig. 2: Photo Meyer-Eppler.

What we can extract from this story is that it was not the structure in terms of the construction of the vocoder itself that animated new musical ideas or new realisations about old innovative concepts of music, but rather it was the way in which the vocoder could be handled to manipulate sound, that is, a way to handle sounds, that initiated a new beginning.

The focus on the role of manual dimensions we get from studying the history of electronic music is reinforced by the observation that, in the first electronic studios for music, the technicians played a role that cannot be overstated. Technicians played the role not only of mediators between artist and technique, but of initiators or even inventors of creative work.

In such a way, Heinz Schütz, the first technician of the electronic studio of the NWDR, invented the method of 'milking' a tape recorder by rhythmically changing the force on the tape and pulling it away from its regular path on the tape machine. This functioned as follows: The tape with recorded sound was placed on the left tape reel and passed by the playback head. There was no tape on the right reel but the brake was unlocked. By pulling the tape behind his back with his right hand, Schütz produced a sound characterised by a more or less quick ascent due to the tempo of his arm motion, followed by a progressive decay due to deceleration, which depended on the inertia of the rotation of the left tape reel. The tape dropped out of his right hand as he rhythmically played with changing the dynamics of his arm motion, as if he wanted to start a motor with the help of a cord. The bell-like sounds Heinz Schütz composed for his piece *Morgenröte* (1951) suggest this both rhythmical and smooth procedure.

Meyer-Eppler himself often filled the role of a technician because he was a hands-on man. But Meyer-Eppler was first and foremost a scientist: his technical doings always reached the state of proper experiments that were integrated into theories or even led to theoretical approaches. Meyer-Eppler's understanding of acoustics always focussed on acoustics as a theory of the audible instead of as a theory of sound in a purely physical manner. In his experiments, he produced phenomena that were dependent on the instruments he used (for instance, the tape recorder). Thus, aspects of reality were enhanced and became analyzable in their psychoacoustical effects. In Meyer-Eppler's work, we see the type of constructive experiment that will be one of our subjects later on, related to Michael Heidelberger's classifications of experimental methods. One type of sound example that Meyer-Eppler presented to young composers to sensitize them to the great effects of simple technical variations was the deceleration of electronic sounds. The hand-operated play with changing speeds of the tape recorder never failed to astound audiences in the 1950s because the acoustic effect was extreme. Melodies were changed into pure rhythmical trembling.

In the technical world of the 1950s, disruption in speech and music was an everyday phenomenon (consider disrupted radio reception or interferences in telephony). Meyer-Eppler re-enacted those phenomena in order to study closely their effects on hearing and understanding and to find laboratory-confirmed rules. This led to his famous theory of information, rich in detailed observations and full of cultural references concerning modalities of communication. In his broadcasting, Meyer-Eppler showed the effects of disruption, of filtering, and of different speeds for speech and music.

Meyer-Eppler undertook a noteworthy type of experiment that appears very relevant today in the current discussion of performance contexts and ostensively illustrates the problems of the obstinacy of media. The experiment's subject might be titled 'the inner dynamics of technical deficiencies.' On the occasion of the Darmstädter Ferienkurse 1952, Meyer-Eppler, together with Robert Beyer, the *tonmeister* of the NWDR, demonstrated new possibilities for electronic composing. The young composers listened to some sound experiments (*Klangexperimente*) – the name Meyer-Eppler gave his short tape recordings that resulted from his acoustical settings. Most of those settings were very traditional, constructed of several layers of different sounds. In contrast to the static orchestral architectures, these were dynamic sound experiments, such as the one discussed before. A 100-Hz tone was iteratively overlaid by itself, beginning with the tone impression and leading continuously to a rhythmical noise. What caused this rhythmical noise was mainly the increasing noise of copying and re-copying, one of the most annoying accompaniments of the tape-recorder technique at this time.

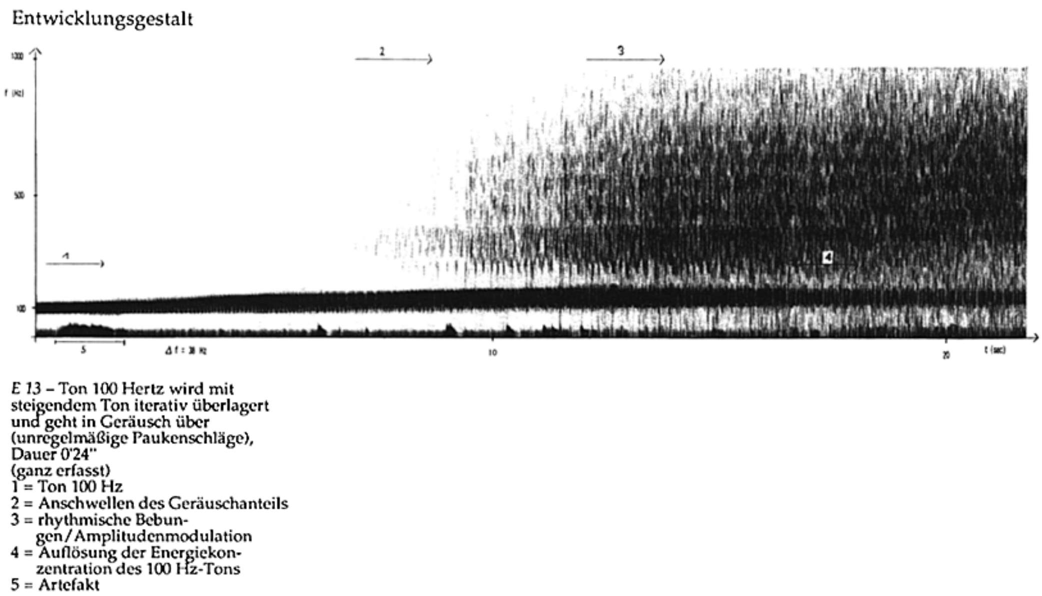

Fig. 3.

Musical theories could emanate from this sort of experiment, and a studio for electronic composition could be designed. Meyer-Eppler never asserted claims to being a composer, and composers never felt obliged to follow strictly his style of sound experiment or his advice. The first thing Karlheinz Stockhausen did when he entered the Cologne studio in 1953 was to remove the melochord and trautonium, the electric instruments installed by Meyer-Eppler.

Fig. 4: First equipment of the Studio for Electronic Music at NWDR Cologne in 1953.

But Meyer-Eppler's sound experiments presented benchmark data for a range of possibilities that could be augmented with one's own compositional ideas. From today's perspective, those sound experiments established analogue sound modifications in a music-oriented context:

– Continuous handling of controlling devices (slide control and knob control)
– Successive addition of sound components
– Loops
– Manipulation of the conditions of the recording medium (in the tape recorder, for example, speed variation, direction of playing/forward-backward)
– Sound effects (e.g. reverberation, frequency shifting, filtering)

An Aesthetic Theory of Action

Sound is ephemeral. Hence, music needs other media than sound to remain perceptible. The old question of wherein the essence of music exists – whether in the score, in the performance, in the mind of the composer, or in the mind of the listener – can not yet be answered definitively by musicians or by musicology. Obviously, music resides inside the media that people are dealing with 'as music.' And those media change from act to act among written forms, instruments, words, sounds, and gestures. Therefore, we consider music as being characterised by intermediality, which describes the specific qualities resulting from the relationships among the media that are activated to give presence to music. What are the basic elements of the aesthetic theory of action exemplified by music? Some preliminaries first.

Firstly: What does the adjective 'aesthetic' mean when we speak about acting?

We would like to follow Wolfgang Welsch and widen his concept of 'aesthetical thinking.'[4] It is twofold: there is *Sinneswahrnehmung*, sensory perception, and *Sinnwahrnehmung*, perception of meaning. Both are interwoven in a particular way in the aesthetic domain. Siegfried J. Schmidt argued in his early project of empirically studying literature that we have to define which acts are to be considered aesthetic and which are not. This constructive approach re-emerges in the face of the aesthetisation of everyday acts and products.

Secondly: The differentiation of types of aesthetic acts doesn't reinforce the accepted separation of productive, receptive, performative, and mediative functions in music. Productive acts are basic to all musical acts including composing (generating structures), listening (reconstructing the ephemeral sound), and performing (creating sound from notation).

Thirdly: We do not distinguish categorically between the visible acts and invisible acts – motivational psychology calls them 'inner acts' – of cognitive and emotional processes.

Fourthly: Human acts are considered to be multilayered, and consequently, there might be different acts at the same time referring to the same person. This has important consequences for the interpretation of performative specifics such as the efficiency of acts, phenomena of failure, subversion, never-ending processes, etc. The *Sonderforschungsbereich des Performativen* at the Freie Universität Berlin has made important observations in this field.

Fifthly: The German *Handlungstheorie*, originating in sociology, is strongly oriented towards utilitarian, rational, purpose-built (*zweckrationale*) enterprises. Aesthetic contexts are not bound to these sorts of acts. On the other hand, we do not follow the often applied categorical distinction between rationality in real life and irrationality in the realm of art. Art may function rationally or irrationally. To produce an aesthetic theory of action as a flexible instrument to describe all kinds of aesthetic situations, we use defining elements – who acts how, why, when, with what aim, intention – as scalable parameters. It could be that there is a nameable author/composer or not. It could be that there is an identifiable aim or not ...

Thus we arrive at a multidimensional architecture of act-dimensions. What I mean here is a model of aesthetic action, but not a model in the sense of an imitative reproduction. The computer scientist Bernd Mahr (TU Berlin) named these sorts of models 'conceptual models'[5]: models that can be adapted to all kinds of concrete configurations, describing the theories behind the elements of the model itself. Theories about creativity, psychology, sociology, and causality lie behind all the hierarchies that structure the parameters of definition.

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4 Wolfgang Welsch, "Zur Aktualität ästhetischen Denkens," in: idem, *Ästhetisches Denken*, 3d ed., Stuttgart: Reclam, 1993, pp. 41-78.

5 Bernd Mahr, "Modellieren: Beobachtungen und Gedanken zur Geschichte des Modellbegriffs," in: Sybille Krämer and Horst Bredekamp (eds.), *Bild – Schrift – Zahl*, Munich: Fink, 2003, pp. 59-86.

We can classify aesthetic acts according to parameters or by clustering them according to their positions on the related hierarchies. I would like to pick three sorts of aesthetic acts in order to show their closeness to experimental methods: the acts of forming, arranging, and manipulating.

Acts of Composing – Forming, Arranging, and Manipulating – Compared to Producing, Representing, and Constructing as Experimental Methods

Fig. 5: Air pump

Michael Heidelberger's classification scheme gives us three categories of experimental instruments which characterise experimental methods. The thing that experiments deal with is not called material, but reality. Reality plays the role of something to be transformed, to be analysed, and to be domesticated. The productive instruments contribute to expanding the reality of man. They generate phenomena not producible without the instrument. The air pump generates a vacuum that couldn't be experienced without that pump. What results from the productive experiment doesn't exist outside the use of the given instruments. In the same manner, particle accelerators nearly continuously produce new building blocks of matter.[6]

Heidelberger speaks of limited productive instruments as those that improve the capacity of our senses or analyse appearances, e.g. the microscope. They do not produce phenomena per se, but reveal them under conditions that are not accessible without the instrument.

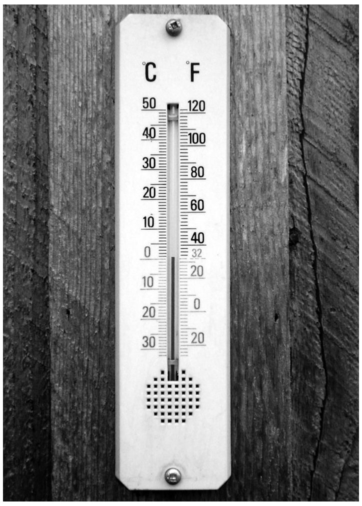

Fig. 6: Thermometer

Representative instruments are designed to present the dependency of one phenomenon on another phenomenon by symbols on the instrument itself.[7] Examples of representative instruments are the clock, scale, thermometer, and galvanometer. The mercury thermometer transforms phenomena perceivable as heat into a visual phenomenon (dilation of the mercury column).

The instruments called constructive and imitative are aimed at controlling the conditions of a phenomenon in order to tame it. By the use of these instruments, incommoding facts of the phenomenon being studied can be eliminated as far as possible. The Leyden jar, invented in 1745, was not designed to detect electricity nor to quantify it. Electricity was to be accumulated and stored by Leyden jar. The idea was to manipulate, to fashion electricity at the moment when it has been isolated under laboratory conditions.

6 Ibid., p. 81.
7 Ibid., p. 82.

Fig. 7 a.

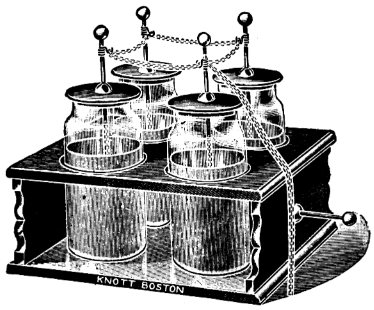

Fig. 7 b.

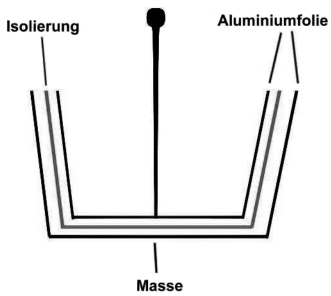

Fig. 7 c.

Other constructive instruments imitated and scaled down the lightning strike.[8] Domestication of natural phenomena is a strong motive for experimental settings.

[8] Ibid., p. 83.

Acts of Forming in Art-Related Contexts

Aesthetic acts are focussed on something perceivable, sometimes called ‘material’ (Adorno coined the term ‘historical material’). This material is never as monomedial as it seems to be. The material a composer works with is not only sound, but also pictures, scripts, words, machines, and so forth. Here we see that we have to argue in a media-critical way when we address an aesthetic theory of action. Forming, arranging, and manipulating music require dealing with specific cultural techniques such as numbers, graphics, sound storage media, and musical instruments.

Systematising compositional acts doesn’t lead to the drafting of a sort of ideal way of composing. There is no succession of acts that can be predicted, and there might be different layers of acting at the same time. For example, finding material and forming material are different categories of acting. They can be executed in any order or even at the same time.

Forming material means creating gestalt from the material or ‘generating formed material.’ Where does the gestalt of music come from? Melodic gestalts are shaped by the characteristics of intervals, by tonal phrases. Melodic gestalts stem from the harmonic system of the music. In terms of Heidelberger’s classification, a *productive method* is crucial to all kinds of forming acts. Do composers use productive instruments when they form their melodies, motifs, rhythmical gestalts? When we allow the term ‘instrument’ to be sufficiently flexible, we identify abstract instruments in the melodic and stylistic models a composer uses to derive the gestalts. Further there are literally the musical instruments that form sounds in an ever-characteristic way. Productive instruments can also be seen in technical instruments (effect devices), especially in electroacoustic music, which have an impact on the gestalts they produce. Software programmes are also used as productive instruments.

In order to form sounds, composers instrumentalise intermedial relationships as well. When Stockhausen created a series of evolutionary forms for the sounds in his electronic piece *Gesang der Jünglinge*, the gestalts stemmed from graphic forms. ‘Going up’ and ‘going down’ signal the direction in which values of a given scale should be followed.

value	3716524	7453261	1564372	6342157	5231746	2675413	4127635
duration	3716524	1327456	5427163	4617235	7154263	6741532	2753146
formants	3716524	6741325	4736521	1425763	2476135	7453126	5364721
time	3716524	5136742	7612435	2173546	1623457	4512367	6412357
pitch	3716524	2675134	6253714	7256314	4315672	5136274	1275463
dynamic	3716524	4512673	2341657	5734621	6547321	1327645	7536214
timbre	3716524	3264517	3175246	3561472	3762514	3264751	3641572

VALUE	4						
	8	7.25	6.6	5.95	5.4	4.9	4.4
	16	14.5	13.1	11.9	10.8	9.7	8.8
	32	29	26.3	23.8	21.5	19.5	17.7
	64	58	52.5	47.6	43.1	39	35.3
	128	116	105	95.1	86.2	78	70.7
	256	231.9	210	190.2	172.3	156	141.3
	512	463.7	420	380.4	344.6	312.1	282.6

DURATION (1) −1/6 (2) 0 (3) +1/6 (4) +2/6 (5) +3/6 (6) +4/6 (7) +5/6

GROUP OF FORMANTS

number (1) 1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 1 (7) 2

from among the following possibilities:

1	12	123	1234
2	13	124	1235
3	14	125	1245
4	15	134	1345
5	23	135	2345
	24	145	
	25	234	
	34	235	
	35	245	
	45	345	

EVOLUTIONARY FORMS

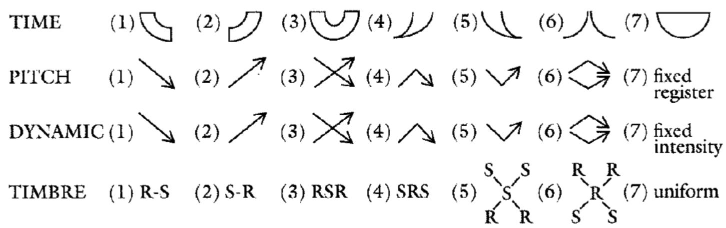

Fig. 8:
This diagram shows a combination of various compositional sketches concerning the architecture of complex sounds in Stockhausen's electronic piece *Gesang der Jünglinge* (1956). It contains the complete serial grid, and the grid of the durations of reference, as well as the scale of variation for each dimension. There are four temporal parameters in the work:
1. Value: the fundamental duration, which regulates the intervals of entry between successive complexes.
2. Duration: the actual duration of each complex obtained by a positive or negative transformation of the value. Depending on the duration/value ratio, the complexes will be partially superimposed or will be separated by a silence.
3. Group of formants: the number of 'octaves of durations' within which the durations will be taken for carrying out the various harmonic subdivisions of the duration, the octave grouping being limited to five octaves.
4. Evolutionary form in time, where the concepts of attack and decay of sound take place.

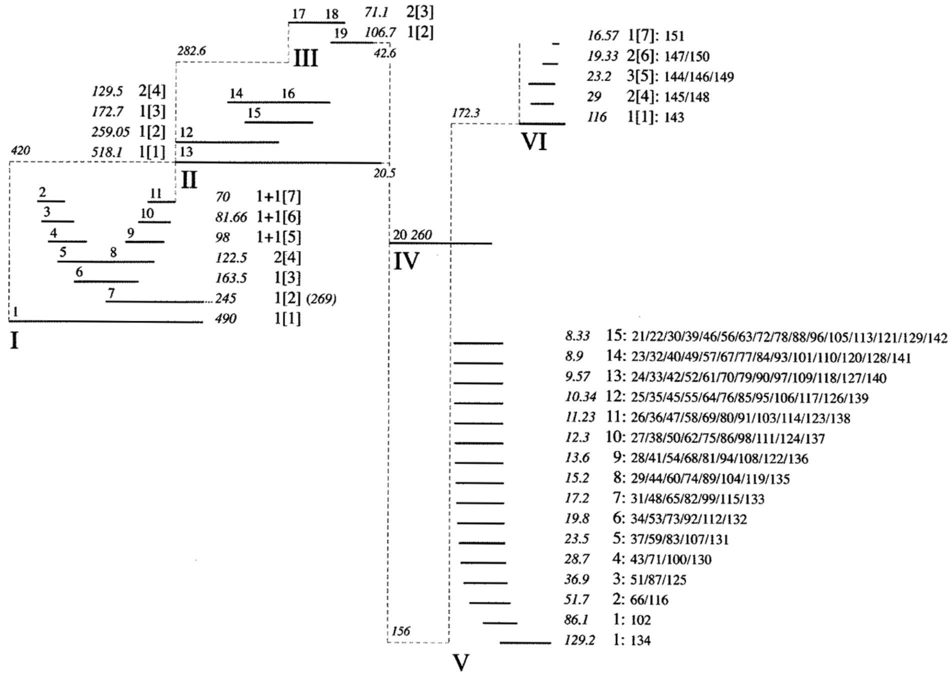

Fig. 9:
Application of evolutionary forms in time. Spectra I and II should make clear the difference between two spectra with settings into vibration from high to low and symmetrical decay, the first hollow, the second solid. However, because of its group of formants, spectrum II does not have enough elements to render this difference perceptible. The evolutionary forms of movement of spectra III, V, and VI are simple, either a setting into vibration from high to low (III and V) or a decay from low to high (VI). The appearance at the end of spectrum V expresses the difference between the 'pointed' spectra and those that are denser at the end (III and VI). With only one component, complex IV obviously cannot describe any evolution.

There are also metaphorical productive instruments. We note that what Stockhausen calls 'rhythmic formant' is a relatively faithful adaptation of the formant notion from acoustics, consisting of more or less dense frequency regions, which give each sound its specificity. In the final parts of *Zeitmaße* and *Gruppen,* the instrumental works composed on the basis of rhythmic formants, as well as in the related theory formulated in the article "wie die Zeit vergeht,"[9] 'formant' is made the equivalent of 'rhythm harmonic,' meaning therefore an integral periodic subdivision of the fundamental duration. The vertical proportional grouping in bands with a width of one octave each, characteristic of the first complexes composed for *Gesang der Jünglinge*, is later replaced by an individual serial treatment of each rhythm harmonic.

9 Karlheinz Stockhausen, "wie die Zeit vergeht..." (1956), in: Herbert Eimert (ed.), *Die Reihe: Informationen über serielle Musik*, vol. III, Vienna: Universal-Ed., 1957, p. 13ff. Reprint in: Karlheinz Stockhausen, *Texte zur elektronischen und isntrumentalen Musik*, vol. I, Cologne: DuMont, 1963, p. 99-139.

Acts of arranging

Every composer arranges his musical material by structuring, classifying, building up families of sounds, deriving motifs, etc. In this pre-compositional process, representative instruments, in the sense of Heidelberger, are used. To pre-organise sound material, serial composing affixes series, forms tables of permutation, uses scales, determines parameters of sound manipulation, develops systems of distribution, and even uses mathematical concepts – these compositional techniques can be interpreted as acts of arranging. See the serial table for Pierre Boulez's *Première étude de musique concrète.*

1	6	3	4	10	11	5	12	7	9	2	8
6	11	8	9	3	4	10	5	12	2	7	1
3	8	5	6	12	1	7	2	9	11	4	10
4	9	6	7	1	2	8	3	10	12	5	11
10	3	12	1	7	8	2	9	4	6	11	5
11	4	1	2	8	9	3	10	5	7	12	6
5	10	7	8	2	3	9	4	11	1	6	12
12	5	2	3	9	10	4	11	6	8	1	7
7	12	9	10	4	5	11	6	1	3	8	2
9	2	11	12	6	7	1	8	3	5	10	4
2	7	4	5	11	12	6	1	8	10	3	9
8	1	10	11	5	6	12	7	2	4	9	3

Fig. 10: Pierre Boulez, serial table for *Première étude de musique concrète*.

In his analysis of that piece, Pascal Decroupet explained:

> So as to transfer the principle of serialised pitch organisation to other acoustic dimensions, and thus provide the work with a higher level of musical organisation, Boulez borrowed the concept of function from mathematics. In a letter to John Cage dated August 1951, he writes: "It is possible to consider that a series, in general, may be defined as a function of frequency f(F), acting on the functions of duration f(t), of intensity f(i) etc. […] where only the variable changes, the function remains constant. Overall, a serial structure can be globally defined as ? {f(F), f(t), f(i), f(a)}." The numerical symbolisation of sound allowed Boulez to achieve the uniform manipulation of pitch, duration, dynamics and articulation, each provided with scales of gradation designated as 'chromatic.' Another ramification of his notion of function

> can be observed in the serial tables, where the order of transposition reproduces the initial function. In other words, the prime form of the series is used to align the twelve transpositions of the row. Such a table constitutes a 'function of functions' that can be translated directly into the work.[10]

Acts of manipulating

Electronic effect devices (frequency-shifting, reverberation, envelope shaper etc.) are instruments that manipulate sounds. As Heidelberger described in his examples of manipulating electricity, it is important to imitate nature in order to domesticate it. The imitation of the nature of sound forms the basic orientation in the concepts of sound synthesis which allow particular effect devices to be designed. But there is something else that makes constructive instruments important for composing. The *constructive instruments*, as Heidelberger defined, are intended to render phenomena at a humanly manageable size. The important acts can be explained by the method of the composer Roland Pfrengle, known for his interactive style of composing. Pfrengle was mainly interested in the whole of the instrumental sound. There is a piece called *Innen*, in which the rare, huge contrabass flute is played. Its sound holds many aspects that are not directly manipulable for the composer. In order to 'domesticate' the sound, Pfrengle first had the performer play some sounds and phrases. He recorded them and used them in his studio, 'testing some algorithms', as he put it. His project – based on spectral analysis – was to use single aspects of the flute's spectrum for strange modulations or for interactively triggering other sound processes. But, at a higher level of acting, his main project in this piece was to re-set the interactively anatomised and modified sound of the huge flute within the whole piece, thus evaluating the inner life of the instrument through its sound opulence. We can interpret Pfrengle's testing algorithms as constructive instruments in the sense of the Leyden jar, minimising the complex sound of the contrabass flute in manageable sound experiments and allowing them to be controlled.

10 Pascal Decroupet, "Floating Hierarchies: Organization and Composition in Works by Boulez and Stockhausen During the 1950s," in: *A Handbook to Twentieth-Century Musical Sketches*, ed. by Patricia Hall and Friedemann Sallis, Cambridge: Cambridge University Press, 2004, p. 148.

Standardizing Aesthetics: Physicists, Musicians, and Instrument Makers in Nineteenth-Century Germany[1]

Myles W. Jackson

The late eighteenth and nineteenth centuries, as many scholars have argued, was the period of scientific standardization throughout Europe and in the United States. In one sense my lecture today is similar to the works of Ken Alder on the quantification of the meter in late eighteenth-century France; Kathy Olesko's and Norton Wise's studies on the importance of standardizing units of scientific measurement in Prussia, and Simon Schaffer's pioneering work on the standardization of the Ohm by nineteenth-century British metrological laboratories, and most recently Peter Galison has written on the politically charged negotiations involved in the formation of the international bureau of weights and measures in 1875 and the final sanctioning of the meter in 1889.[2]

My paper will focus on the role physicists played throughout the nineteenth century on the standardization of pitch, which shares with these other accounts the inextricable links among science, technology, economics, and politics. But I would suggest that the standardization discussed here also possesses a unique quality. There is clearly an aesthetic issue at stake, as the French composer Hector Berlioz suggested when serving on the committee to establish the French *diapason normal*. This aesthetic quality forms the thesis of this paper. I am particularly interested in what musicians and scientists alike called "a scientific" and "mathematical aesthetic" of standardizing pitch.

Throughout the nineteenth century, a cacophony of musical pitches seems to have plagued European orchestras and traveling virtuosi. Not only did different countries possess different

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1 This article is based on portions of two chapters of my book, *Harmonious Triads: Physicists, Musicians, and Instrument Makers in Nineteenth-Century Germany*, Cambridge, MA and London: MIT Press, 2006. I thank The MIT Press for permission to use that material.

2 See, for example, the collection of essays Tore Frängsmyr, J[ohn] L. Heilbron, and Robin E. Rider (eds.), *The Quantifying Spirit in the Eighteenth Century*, Berkeley and Los Angeles: University of California Press, 1990. Alder has offered a very enlightening account of the quantification of the meter in late eighteenth-century France, illustrating that the rhetoric of "natural" standards belied the social and economic interests of those seeking a national standard. See Ken Alder, "A Revolution in Measure: The Political Economy of the Metric System in France," in: M. Norton Wise (ed.), *The Values of Precision*, Princeton, NJ: Princeton University Press, 1995, pp. 39-71. Schaffer has provided a compelling account of how standardization in Victorian Britain, in the form of metrology, linked the inner workings and relationships of British physics laboratories with technical and economic projects in society, such as cable telegraphy. See Simon Schaffer, "Late Victorian Metrology and its Instrumentation: A Manufactory of Ohms," in: Robert Bud and Susan E. Cozzens (eds.), *Invisible Connections: Instruments, Institutions, and Science*, Bellingham, WA: SPIE, 1992, pp. 23-56. See also idem, "Accurate Measurement Is an English Science," in: M. Norton Wise (ed.), *The Values of Precision*, Princeton: Princeton University Press, 1995, pp. 135-172. For a compelling account dealing with the ethics and trustworthiness of measurement, see Graeme J. N. Gooday, *The Morals of Measurement: Accuracy, Irony, and Trust in Late Victorian Electrical Practice*, Cambridge: Cambridge University Press, 2004. Galison details the scientific, technological, social, economic and political pressures (particularly from the European and American railway companies) to standardize time in the 1880s. See Peter Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time*, New York: Norton, 2003, pp. 84-155.

pitches for *a'*, orchestras in the same city sharing the same pitch was a rarity, indeed at times they varied in pitch by as much as a semitone. In addition to the myriad of *Kammertöne* throughout Europe, a gradual sharpening of the various concert pitches was well underway by the 1820s. As early as 1802 Heinrich Christoph Koch had noted in his seminal *Musikalisches Lexikon* that *Kammertöne* were gradually rising.[3] Generally, with the formation of large orchestras and musical scores written to accommodate such orchestras, tonal color catered to the higher instrumental range rather than the human voice, or the *vox humana*, as had been the case during the Middle Ages. The rapid rise in pitch was perhaps greatest in the German territories. Whereas *Kammertöne* throughout Prussia and Saxony had been consistently lower than those in Vienna and Paris during the early years of the nineteenth century, by the 1830s German pitches were slightly higher than in most French cities and Vienna.

Mid-nineteenth-century scholars have pointed to a dramatic rise in pitch after the Congress of Vienna in 1816. Czar Alexander of Russia, who was also the colonel of a regiment during the Napoleonic Wars, presented his military band with a set of musical instruments, newly made by the Austrian instrument maker, Stephan Koch, for a performance at the Congress.[4] Many reviewers commented on the brilliance of the band's tones, arguing that the sharper pitches were well suited to the horns. Indeed, military bands preferred the higher, brighter pitches. And this resulted in the mean pitches in theaters rising as well. During the late 1810s, the *Kammerton* began its inexorable rise that was to last well into the mid-1880s. Although the phenomenon originated in Vienna, Dresden rose slightly during the 1820s, but eventually succumbed to their neighbors to the southeast. Leipzig's pitch, although sharpened over time, was much more consistent than Dresden's. Berlin pitches had risen from approximately 430 vps from 1806 to an average of 442 in 1834. By 1859 the average Berlin pitch for *a'* soared to 452 vps.[5]

Variation in pitch did not merely alter the aesthetic effect of pieces, it had an anatomical consequence as well. Vocalists in particular were distressed by the lack of pitch standardization. Throughout the first four decades of the nineteenth century, the *Allgemeine musikalische Zeitung* often reported the various diatribes against the rising pitch. Sopranos in particular protested most ferociously: the prima donnas carrying along a tuning fork to performances, insisting (with limited success) host orchestras tune to them. In 1814 the philosophers Christian Friedrich Michaelis and Johann Gottfried Schicht had pleaded for a common pitch for singers and orchestras across Europe. They argued how the necessity of singers to adjust to orchestral pitches, which differed as much as a full tone, was both exhausting and deleterious to their health.[6] The Parisian prima donna Mme. Branchu forced the opera to lower its pitch in the early 1820s, as she

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3 Heinrich Christoph Koch, *Musikalisches Lexikon, welches die theoretische und praktische Tonkunst, encyclopädisch bearbeitet, alle alten und neuen Kunstwörter erklärt, und die alten und neuen Instrumente beschrieben, enthält*, Frankfurt/M.: August Hermann der Jüngere, 1802, p. 822 and Bruce Haynes, *A History of Performing Pitch: The Story of "A"*, Lanham, MD and Oxford: Scarecrow Press, 2002, p. 312.

4 Karl Näke, *Ueber Orchesterstimmung: Den deutschen Kapellmeistern bei ihrer Versammlung in Dresden, den 28. September 1862, gewidmet*, Dresden: Liepsch und Reichardt, 1862, p. 28.

5 Alexander J. Ellis, "On the History of Musical Pitch," *Journal of the Society of Arts* 28 (1880), pp. 293-336, here p. 319, and pp. 401-403.

6 C[hristian] F[riedrich] Michaelis and J[ohann] G[ottfried] Schicht, "Aufforderung zur Festsetzung und gemeinschaftlichen Annahme eines gleichen Grundtones der Stimmung der Orchesters," *Allgemeine musikalische Zeitung* 16 (1814), cols. 772-776.

feared the high pitch would result in a premature loss of her voice.[7] Arias requiring the mastery of very high pitches as well as pieces containing falsettos were particularly difficult, as the singers touring Europe were forced to readjust their ears and vocal chords to the particular *a'*, which that orchestra chose. The problem became particularly acute by the mid-nineteenth century, when vocalists and instrumental virtuosi touring Europe reached a feverish pitch.

The eighteenth and early nineteenth centuries witnessed an increase in appeals for the standardization of pitch from acousticians as well. In 1800 Ernst Florens Friedrich Chladni had recommended 128 simple vps (64 Hz) for the organ pipe 8-foot *C*, which corresponds to a tempered *a'* of 430 vps.[8] *C* was the pitch often used as the fundamental tone in tuning other pitches, and 128 could be divided by two for the lower octaves and multiplied by two for the higher ones. Granted this number was within the range of pitches for 8-foot *C*, Chladni was more interested in the mathematical ease of determining the absolute number of vibrations. He sought a universal standard pitch: "since the nearly ubiquitous increase in pitch has done nothing for performance, it would be most advisable to accept a standard pitch where the number of vibrations in one second is a factor of two for every octave of *C*."[9] Such a pitch could be measured accurately and easily with a tonometer. Despite Chladni's valiant efforts, his advice fell on deaf ears.

One of the German territories' leading experimental physicists of the period, Wilhelm Weber also addressed the problem of a lack of standard pitch. Weber's acoustical work not only led to the improvement of musical instruments; he was also dedicated to standardizing pitch. His well-known commitment to the standardization of scientific phenomena (particularly in electrodynamics) dates back to some thirty years to his reed-pipe research. And Weber certainly played a pivotal role in the standardization of physical constants. Hence, it should come as no surprise that one of Weber's greatest contributions to music was in the rigorous application of experimental physics to musical-instrument design with the view to standardize, particularly pitch. He was particularly interested in the effects of standardization in general on trade.

In his article "Ueber die Construction und den Gebrauch der Zungenpfeifen," Weber discussed the suitability of his compensated reed pipes for establishing a standardized pitch (*Normalton*).[10] He argued that "[b]ecause there is no instrument known, other than the reed pipe, which possesses the advantage that it keeps its pitch constant with the various strengths of its tone, I believe that reed pipes can be recommended as the most suitable apparatus for pitch (*Normalton*), in order to achieve an even greater precision (*Genauigkeit*), where the previously used tuning forks do not suffice."[11]

Just as the determination of physical standards garnered him fame as Germany's leading experimental physicist of the nineteenth century, Weber was interested in establishing a standard

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7 Haynes, *A History of Performing Pitch*, p. 330.

8 E[rnst] F[lorens] F[riedrich] Chladni, "Eine neue Art, die Geschwindigkeit der Schwingungen bei einem jeden Tone durch den Augenschein zu bestimmen, nebst einem Vorschlage zu einer festen Tonhöhe," *Annalen der Physik* 5 (1800), pp. 1-9, here p. 8. See also Aristide Cavaillé-Coll, *De la détermination du ton normal ou du diapason pour l'accord des instruments de musique*, Paris: de Soye et Bouchet, 1859, p. 13.

9 Chladni, "Eine neue Art, die Geschwindigkeit der Schwingungen bei einem jeden Tone durch den Augenschein zu bestimmen," p. 9. All translations are mine, M.W. J.

10 Wilhelm Weber, "Ueber die Construction und den Gebrauch der Zungenpfeifen," *Annalen der Physik und Chemie*, new series, 16 (1829) (original series, 92), pp. 193-206.

11 Ibid., p. 194.

pitch for musical instruments and voices, upon which everyone could agree. He lamented "[w]e are still far removed from possessing a generally accepted scientifically established standard pitch. And it is now very difficult to come to an agreement on the tuning of instruments. It is worthy of such an extensive art as music, and of such an important branch of industry, as instrument making is, to test the object in question from many sides."[12]

Reed pipes were not the only instruments that piqued Weber's curiosity. He was interested in the monochord as well, since it was simultaneously a physical and musical instrument. Indeed, this fascination, using the same mechanical device to investigate differing physical phenomena relevant to a plethora of disciplines, including music, informed Weber's work on the monochord. Weber discussed his instrument, to which he referred as both a monochord and tonometer, which was built to his demanding specifications by J. August Oertling, the mechanician who built Weber's reed pipes. The instrument was composed of one or more perpendicularly suspended iron strings between two pegs. By altering the length of the weights attached to the string(s), different pitches could be generated. Weber immediately commented upon the various uses for which this instrument could be employed.

> In the hands of an *experimental physicist*, this instrument can be used as a measure of the comparison of tones. And because the pitch of a tone is dependent on the velocity of the repeating vibrations or beats of the sounding body in the same periods, it can assist in measuring the duration of vibrations of the smallest intervals of time, which last from one beat to the next. This instrument can even measure smaller parcels of time than the *Tertienuhren* and all other instruments, which are at our disposal. In the hands of the *instrument maker, the composer, and the practical musician*, the instrument is a standard measure, by which instruments can be tuned, and by which the composer can determine for all future occasions, for which voice his composition is intended. And by means of this instrument a general agreement can be established by all nations on the acceptance of an unchanging pitch.[13]

Once again, Weber wished to achieve a standard pitch accepted by musicians, composers, and physicists.

Weber's monochord was composed of three elements (fig. 1). The first were the strings. He used metal strings (generally made of iron), since those strings, in contrast to strings of catgut or intestine, are not subject to changes in pitch due to dampness or dryness. The second was a device through which the strings could vibrate freely.[14] This apparatus, which surrounds the string but does not hinder its motion, is composed of two crafted steel clamps, *cd* and *ef* in figure 1. Each clamp is composed of two cubes, 1/2 inch thick, *a* and *d*, and *e* and *f*, which must be parallel. The clamps limit the vibrating portion of the string and secure its endpoints without altering its tension.[15] In order to ensure that the string was not flattened by the two clamps, Oertling constructed two half cylinders of steel, which were fastened to each other. Between these two half

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12 Ibid., p. 195.
13 Wilhelm Weber, "Ueber die zweckmässige Einrichtung eines Monochords oder Tonmessers und den Gebrauch desselben, zum Nutzen der Physik und Musik," *Annalen der Physik und Chemie*, new series, 15 (1829) (original series, 91), pp. 1-19, here pp. 1-2.
14 Ibid., p. 5.
15 Ibid., p. 7.

cylinders (fig. 2 in fig. 1) a groove was cut with the same diameter as the string. This cylinder was then fitted into a brass clamp, *defg* (fig. 3 in fig. 1), and tightened with a screw.[16] The third part of the monochord was a wooden tray of a known weight that was suspended from the end of the string. Weights were added to the tray in order to alter the string's pitch.[17]

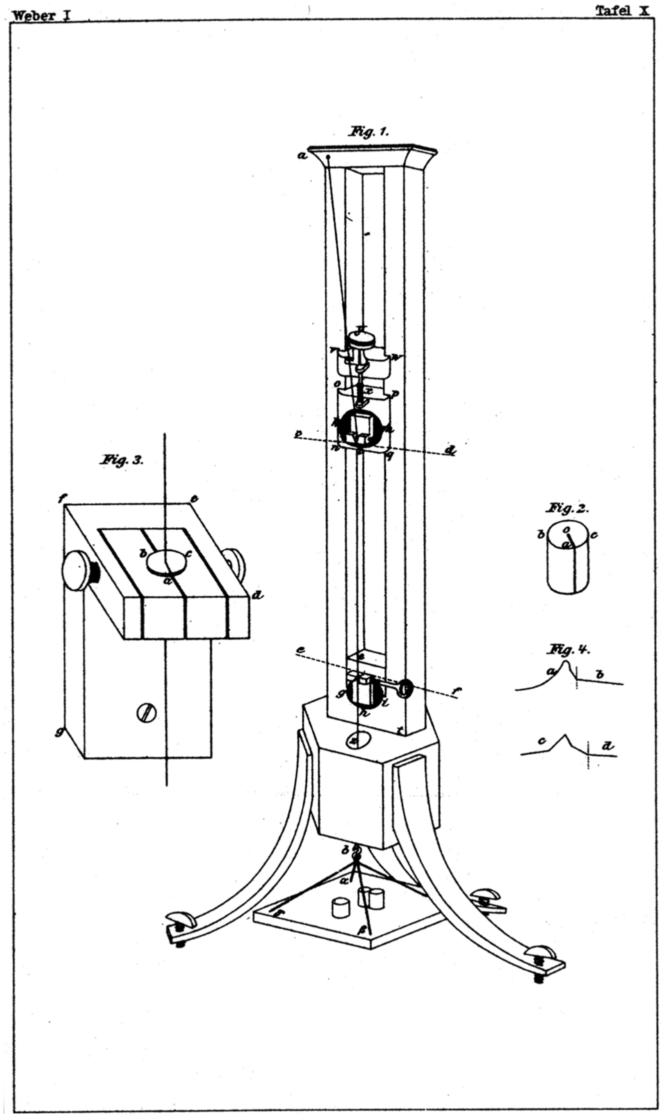

Fig. 1: Wilhelm Weber's monochord (also called tonometer). From: Wilhelm Weber, *Wilhelm Webers Werke*, Hrsg. von der königlichen Gesellschaft der Wissenschaften zu Göttingen, 6. vols., Berlin: Julius Springer, 1892-1894, vol. 1 (1892), table X, pp. 358-359.

Weber then proceeded to demonstrate how his monochord, or tonometer, could be used effectively by the physicist. Included in the numerous possibilities was his suggestion that the

16 Weber sought the advice of the Oberbergrat Schaffrinsky of Berlin, who was well versed in precision mechanical work, for assistance in the design model of the clamp.

17 Weber, "Ueber die zweckmässige Einrichtung eines Monochords oder Tonmessers und den Gebrauch desselben," pp. 8-9.

tonometer be employed to determine the pitch of longitudinally vibrating bodies. One could also ascertain the various properties of these bodies with very high pitches. For example, one could easily and accurately measure the velocity of the propagation of the beat through the air of an organ pipe. Indeed, following the work of Chladni, one could obtain the velocity of the propagation of a beat through all solid materials from the pitch of the longitudinally vibrating string or rod. And since different strings and rods composed of different metals produce beats with differing velocities, Weber remarked that chemists and mineralogists might employ such a device as an assay to differentiate between substances. And, from the velocity of the propagation of the beat, a physicist could study the compressibility (*Compressibilität*) or ductility (*Dilatabilität*) of a particular substance by applying pressure or tractive force.[18]

Weber feared that musicians and musical-instrument makers might be discouraged from using this device. One needed both patience and skill in weighing the strings. And few, if any, musicians possessed accurate enough balances for the required accuracy. Weber, therefore, attempted to ameliorate the problem by using a tested tuning fork (a compensated reed pipe would be too expressive and its precision is not that necessary in this instance) in conjunction with the monochord so that an instrument maker or musician need not burden him/herself with the weighing of the strings. S/he only needed to stretch a string of a known length until it generated precisely the same pitch as the tuning fork.[19] One struck the tuning fork with a mallet and bowed the monochord's string. If one detected beats, then the two sounding bodies did not possess the same pitch. The string was then either tightened or loosened (depending on whether it was too sharp or too flat), until no beats were heard, and then weighed. Weber envisaged the instrument makers shipping a table of weights of the strings along with the monochord. He also hoped that instrument makers would provide a guaranteed tuning fork so that the musician "need not calculate anything, but can simply find the weight of the string for the observed tone."[20] He provided an example of such a table. One last problem from which the tonometer/monochord suffered, which Weber could not easily remedy, was the instrument's cost. In order for it to be useful for musical and physical purposes, it needed to be extremely accurate; therefore, a mechanician needed to build it. Monochords made by Oertling, for example, ranged in cost from 60 to 200 *thaler*.[21] Weber appreciated that most musicians could not afford to purchase such an instrument; however, he did hope that musical institutes, which produced and tested tuning forks, would have such devices at their disposal for general use. He added, "These musical institutes from various lands and parts of the world would gradually establish a generally accepted pitch." Musicians, working hand-in-hand with mechanicians and physicists, could now enjoy the proper standardization that they so desperately sought.

The silk baron and amateur acoustician Johann Heinrich Scheibler of Krefeld, like Weber, yearned for a recognized standard pitch. "It is very much hoped that one will assume *a'* to be the same every where."[22] His reputation began to spread throughout the German scientific community for the precision of his tonometer. He also was renowned among scientific (and to a much lesser extent, musical) circles for his work on attempting to standardize performance pitch.

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18 Ibid., p. 14. For other applications of Weber's monochord/tonometer, see pp. 14-15.
19 Ibid., p. 17.
20 Ibid., pp. 17-18.
21 Ibid., p. 19.

In September of 1834 Scheibler presented his work on the determination of the pitch for *a'* at 440 vibrations per second (Hz, or 880 single vibrations per second). After conducting several experiments with various pitches used in Paris, Berlin, and Vienna, Scheibler decided to choose his *a'* at 440 as "the middle of the extremes between which Viennese pianos rise and fall" due to change in temperature.[23] The pitches of these pianos were determined by a monochord, and the pitch 440 vps was checked by his tonometer. This precise value was approved as the official, national German tone by the physics section of the *Versammlung deutscher Naturforscher und Aerzte* in Stuttgart in September 1834.[24] Scheibler demonstrated the precision of his physical and musical tonometer to the sixty-nine *Naturforscher* of the chemistry and physics section. An error of 1 in 75 vibrations per second greatly impressed the *Naturforscher*, all of whom immediately appreciated the tonometer's potential use in tuning musical instruments.[25] In the following year, Scheibler presented a paper entitled "Mittheilung über das Wesentliche des musikalischen und physikalischen Tonmessers" (Announcement of the Constituents of the Musical and Physical Tonometer) to the chemistry and physics section at the *Versammlung deutscher Naturforscher und Aerzte* meeting in Bonn.[26] Clearly, physicists were very interested in Scheibler's work. Heinrich Ernst Bindseil's *Die Akustik* mentions Scheibler's work on pitch determination using the tonometer.[27]

Scheibler's obsession with precision is noteworthy. Although musicians appreciated that his technique was far more precise than previous methods, his desire for ever greater degrees of precision became an obsession. His was a case of precision for precision's sake, as no ear, not even that of an accomplished musician or keyboard tuner, could hear an error of 1 in 75 vibrations per second. The entrepreneur's fetish for this aesthetic of precision manufacture maps nicely onto his tuning feat. Such a desire resonated with physicists more so than it did with musicians, who initially seemed to ignore Scheibler's pitch. It had no immediate effect on performance pitch. But the Viennese piano maker Streicher tuned his pianos to 440 vps during the late 1830s. And in 1847 an anonymous critic recommended in the *Allgemeine musikalische Zeitung* that 440 by the German standard performance pitch, not because that was the pitch approved by the Association of German Investigators of Nature and Physicians, but rather because it served as a practical pitch for vocalists and an average pitch of those in use throughout the Continent.[28] In that same year,

22 [Johann] Heinrich Scheibler, *Der physikalische und musikalische Tonmesser, welcher durch den Pendel, dem Auge sichtbar, die absoluten Vibrationen der Töne, der Haupt-Gattungen von Combinations-Tönen, so wie die schärfste Genauigkeit gleichschwebender und mathematischer Accorde beweist*, Essen: G. D. Bädeker, 1834, p. 53.

23 Ibid.

24 [Johann] Heinrich Scheibler, "Mittheilung über das Wesentliche des musikalischen und physikalischen Tonmessers," in: *Schriften über musikalische und physikalische Tonmessung und deren Anwendung auf Pianoforte- und Orgelstimmung*, Krefeld: C. M. Schüller, 1838, § 15. This value is slighly flatter than de Prony's average pitch of 442 measured in 1832, Cavaillé-Coll, *De la détermination du ton normal ou du diapason pour l'accord des instruments de musique*, pp. 7 and 13.

25 C[arl][Friedrich] von Kielmeyer and G[eorg] Jäger (eds.), *Amtlicher Bericht über die Versammlung deutscher Naturforscher und Aerzte zu Stuttgart im September 1834*, Stuttgart: J. B. Metzler, 1835, p. 77.

26 Scheibler, *Schriften über musikalische und physikalische Tonmessung*, § 1-15.

27 Heinrich Ernst Bindseil, *Akustik mit sorgfältiger Berücksichtigung der neuern Forschungen*, Potsdam: Horvath, 1839, pp. 604, 621, 625, 629, 630, 681 fn.

28 Hdt., "Die Notwendigkeit einer allgemeinen gleichmässigen deutschen Stimmhöhe," *Allgemeine musikalische Zeitung* 49 (1847), cols. 801-805, here col. 803.

the renowned Bavarian flautist and flute maker Theobald Boehm based his fingering chart for flute playing on a pitch of 440.[29]

Not willing to accept the Scheibler (aka German or Stuttgart) pitch of 440, the French were the first to establish a commission with a view to provide a national standard performance pitch. On 17 July 1858 the French Minister of State created this commission to "[i]nvestigate the means of establishing in France a uniform musical diapason, to fix on a standard of sonority which might serve as an invariable type, and to point out the measures to be passed in order to secure its adoption and preservation."[30] The Commission was comprised of composers, including Berlioz, Gioacchino Rossini, and Giacomo Meyerbeer, as well as two physicists, Jules Lissajous – Professor of Physics at the Lycée Saint-Louis – and César-Mansuète Despretz. The relentless elevation of pitch, it was argued, was deleterious to composers, artistes, and musical instrument makers. In addition, the various pitches being used throughout Europe was "a constant source of embarrassment for concert music" and – just as important – resulted in "difficulties in commercial transactions."[31] The Commission had as its task to find a compromise pitch that would satisfy the instrument makers and instrumental virtuosi, who wanted the higher pitch, and the singers, who demanded lower pitches.

Although the French sought a national standard, they clearly were hoping to establish a pitch that would be accepted worldwide. As Ken Alder has argued, this gesture toward internationalism bears a "Gallo-centric stamp."[32] The Commission requested tuning forks from various cities noted for their musical sophistication throughout France, the German territories, England, Belgium, Holland, the Italian states, Russia, "and even America."[33] Most cities complied, sending both current and antiquated tuning forks from their cities' operas, theaters, and military bands.

The physicists Lissajous and Despretz noted that an overwhelming majority of these forks were above the Scheibler/Stuttgart pitch of 440; indeed, the forks' mean pitch was in the vicinity of 449.[34] They verified the forks' pitches using a Cagniard de la Tour siren with a constant pressure bellows constructed by Aristide Cavaillé-Coll. This ensured the siren's constant pitch.[35] More important, however, was Lissajous subsequent work for the Commission. In 1855 he had invented a method to visualize acoustical vibrations. Not surprisingly, his dissertation written five years earlier proffered a thesis on vibrating bars employing Chladni's method of sprinkling sand on the sounding bodies in order to demarcate the nodal points. Much like Chladni, Lissajous' work was

29 Haynes, *A History of Performing Pitch*, p. 350.
30 As quoted in anon., "The Normal Diapason," *Journal of the Society of Arts* (3 June 1859), pp. 492-498, here p. 492.
31 Ibid., p. 493.
32 Alder, "A Revolution in Measure," p. 51.
33 Anon., "The Normal Diapason," pp. 494.
34 The Commission gathered tuning forks made in 1858 with the following pitches from European cities and concert halls: Brussels 456 vps, London 455, Théatre royal in Brussels 453, Marseille and Lille 452, St. Petersburg and Berlin 453, Milan 450, Prague 450, Leipzig 449, Munich and Paris 448, Pest and the Hague 446, Turin, Weimar, and Wuerttemberg 445, Brunswick 444, and Toulouse 442. They also received six older tuning forks. In 1854 tuning forks from Stuttgart, Gotha, and Vienna all sounded at 443 vps. A tuning fork in St. Petersburg from 1796 made 436 vps, while Mozart's tuning fork in Berlin sounded at 422, and the Grand Opera of Paris tuned to 404 vps in 1699. See Charles Meerens, *Instruction élémentaire du calcul musical et philosophie de la musique*, Brussels: Schott, 1864, p. 11. Again, I have rounded off to the nearest full vibration per second. A. E. Leipp and M. Castellango, "Du diapason et de sa relativité," *La Revue Musicale* 294 (1977), pp. 5-39, here p. 11.
35 Ellis, "On the History of Musical Pitch," p. 298.

committed to rendering the invisible visible: allowing the eye to scrutinize what the ear could not hear. He reflected a light beam from a small mirror attached to a vibrating tuning fork and then from a larger, rapidly rotating mirror onto a screen (fig. 2). After further study, he was able to generate his 'Lissajous figures,' by reflecting a beam of light from mirrors perched on top of two vibrating tuning forks positioned perpendicular to each other (fig. 3). These curves are determined by the relative frequency, phase, and amplitude of the tuning forks' vibrations as depicted on the screen (fig. 4). If one of the two tuning forks is of a standard pitch, one could calibrate the pitch of the second fork by analyzing the resulting Lissajous figures with his invention, the "phonoptomètre," a microscope with a tuning fork attached to the objective[36] (fig. 5). His work on the 1858 Commission resulted in the development of the procedure used by mechanicians for the manufacturing and testing of precision tuning forks.

Fig. 144.

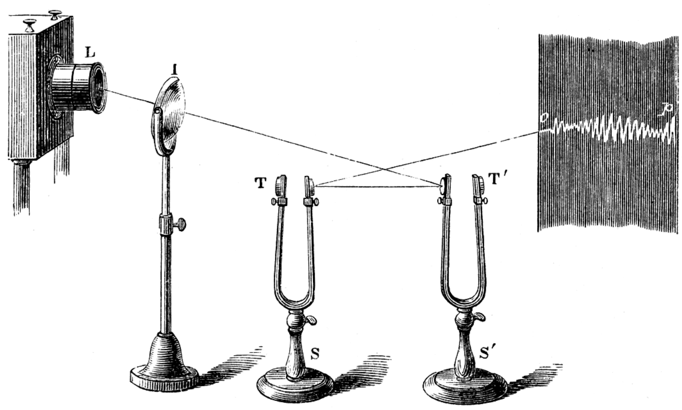


Fig. 2: Lissajous' reflected light beam. From: John Tyndall, Sound, New York: Appleton, 1867, p. 267.

Wishing to seek a fair compromise between the higher tuning forks favored by musical instrument makers and performers and the lower pitches insisted upon by vocalists, a majority of the members settled on a decrease in pitch of a quarter tone, or a standard pitch of 435 vps.[37] "[T]his would sensibly moderate the trouble attending the studies and executions of singers, and thus insinuate itself, so to speak, incognito, into the presence of the public, without causing too great a perturbation in established habits; it would facilitate the execution of ancient master pieces, and would bring us back to the diapason employed about thirty years ago, the period of the production

36 Jules Antoine Lissajous, "Note sur un moyen nouveau de mettre en évidence le mouvement vibratoire des corps," *Comptes rendus hebdomadaires des séances de l'Académie des sciences* 41 (1885), pp. 93-95; idem, "Note sur une méthode nouvelle applicable à l'étude des mouvements vibratoires," ibid., pp. 814-817; idem, "Mémoire sur l'étude optique des mouvements vibratoires," *Annales de chimie*, 3rd ser., 51 (1857), pp. 147-231, and idem, "Sur le phonoptomètre, instrument propre à l'étude optique des mouvements périodique ou continus," *Comptes rendus hebdomadaires des séances de l'Académie des sciences* 76 (1873), pp. 878-890.

37 It turns out that subsequent, more precise measurements of the diapason normal revealed its actual pitch was 435.4 vps. Cavaillé-Coll measured the diapason normal by using his copies of Scheibler's forks. Also Hipkins of Britain determined the diapason normal to be 435.4, as it made 4.1 beats with a fork measured at 439.5 vps. Ellis, "On the History of Musical Pitch," p. 323.

of works of which most have remained on the repertory, and which would thus be in the position they occupied when composed and first represented."[38] And, the Commission added, the value of 435 was close enough to the 1834 Stuttgart/Scheibler pitch of 440 that German orchestras, operas, and theaters could accept the diapason normal without great adjustment.

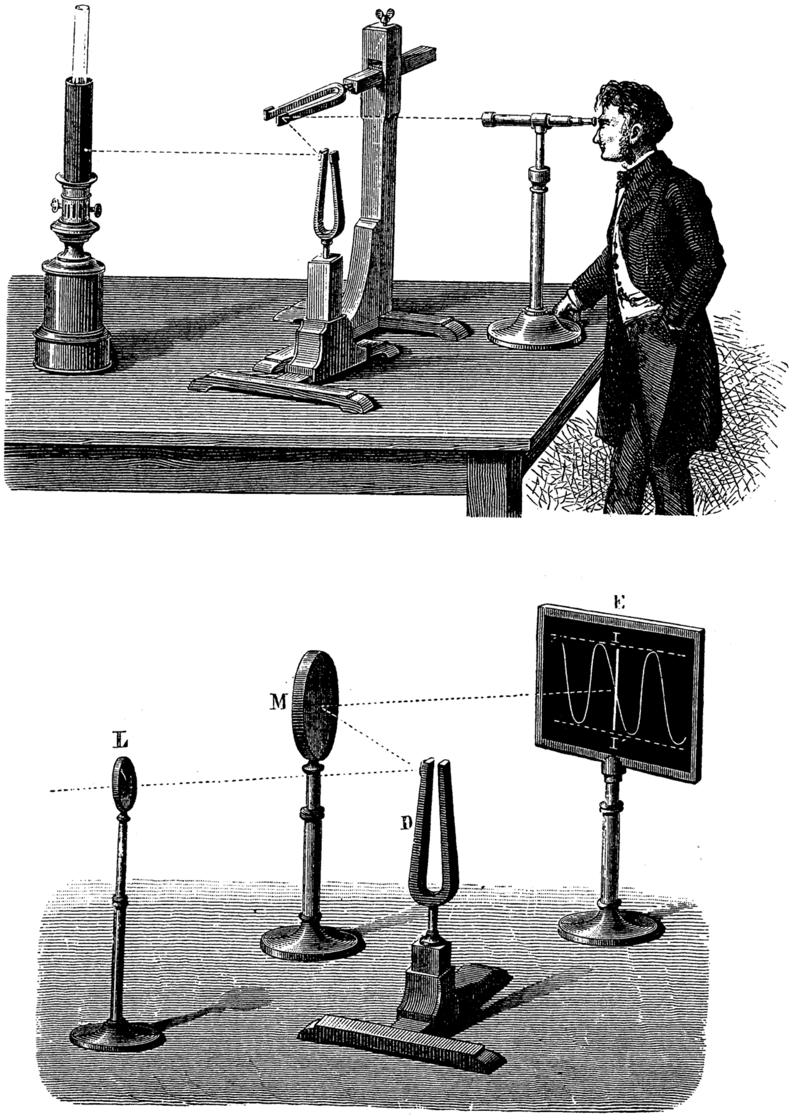
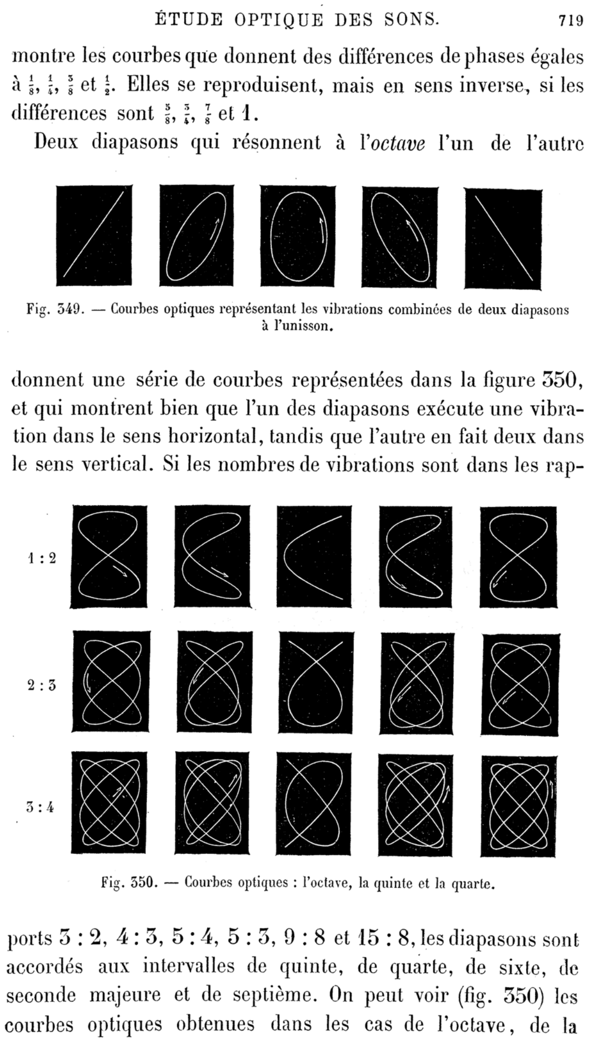


Fig. 3: Lissajois' technique for generating his optical figures. From: Amédée Guillemin, *Le monde physique*, Paris: Hachette, 1881, pp. 716-717.

The Commission advised the *Monsieur le Ministre* that 1) a model tuning fork producing 870 simple vibrations (435 Hz) at 15°C should be constructed by qualified individuals, 2) at some point the *diapason normal* should become obligatory throughout the country, and 3) officers should inspect tuning forks and musical instruments in all French theaters, schools, and other musical establishments. They also requested that the Minister persuade the Minister of War to

[38] Anon., "The Normal Diapason," pp. 496-497.

accept the tuning fork for the military bands as well as convince the Minister of Commerce to permit only musical instruments tuned to 435 vps to compete for prizes given at the Industrial Expositions. And they requested that the *Monsieur le Ministre* exercise his influence over His Excellency the Minister of Public Instruction and Worship for the retuning of organs to the new pitch.[39]


ÉTUDE OPTIQUE DES SONS. 719

montre les courbes que donnent des différences de phases égales à $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ et $\frac{1}{2}$. Elles se reproduisent, mais en sens inverse, si les différences sont $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$ et 1.

Deux diapasons qui résonnent à l'*octave* l'un de l'autre

Fig. 349. — Courbes optiques représentant les vibrations combinées de deux diapasons à l'unisson.

donnent une série de courbes représentées dans la figure 350, et qui montrent bien que l'un des diapasons exécute une vibration dans le sens horizontal, tandis que l'autre en fait deux dans le sens vertical. Si les nombres de vibrations sont dans les rap-

Fig. 350. — Courbes optiques : l'octave, la quinte et la quarte.

ports 3 : 2, 4 : 3, 5 : 4, 5 : 3, 9 : 8 et 15 : 8, les diapasons sont accordés aux intervalles de quinte, de quarte, de sixte, de seconde majeure et de septième. On peut voir (fig. 350) les courbes optiques obtenues dans les cas de l'octave, de la

Fig. 4: Lissajous figures. From: Guillemin, *Le monde physique*, p. 719.

By accepting this national standard, the Commission was convinced that "order and regularity would be established where chance, caprice, and carelessness now sometimes reign [...]."[40] Human voices would no longer be sacrificed. Finally, instrument makers could improve their products and sales as their market would greatly increase as musicians needed to play at this pitch. The Commission concluded their study underscoring the importance of the government in

39 Ibid., p. 497.
40 Ibid.

establishing and enforcing this new standard. "It is not unworthy the government of a great nation to busy itself with questions of this kind, which may appear futile, but which possess a real importance of their own [...]. By directing your attention to the dangers to which an excessive love of sonority may expose musical art, and by endeavoring to establish a rule, a measure, a principle, your Excellency has afforded a fresh proof of the enlightened interest you taken the fine arts generally."[41]

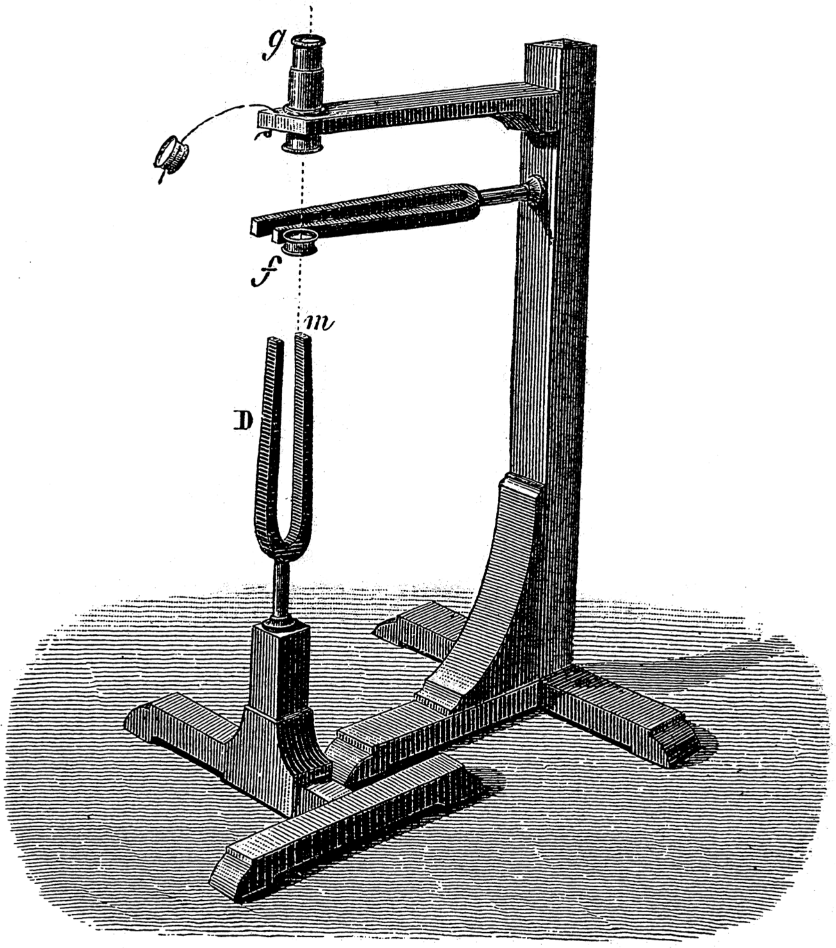


Fig. 5: Lissajois' instrument for precise measurement of pitch. From: Guillemin, *Le monde physique*, pp. 721.

Not to be outdone, the very day the French Commission had filed its report, the Society of Arts in London appointed a fifty-member committee to determine a standard pitch.[42] The British seemed more interested in mathematical pitch than their French counterparts, who viewed the history of pitch more seriously. Sir John Herschel spoke forcibly on behalf of the mathematical purity of tuning. He wanted *c'* to be 512 cycles per second (Hz). Echoing Chladni's view over a half-century earlier, Herschel emphasized that this number could be divided by two, representing the octaves,

41 Ibid.
42 Ellis, "On the History of Musical Pitch," p. 314.

all the way down to the number 2. The committee, however, chose 528. The problem with the British selection, being based on the mathematical, 'natural' intervals of the scale by whole numbers, is that it was based on just intonation for the major *c*-scale only. It could not be applied to equally tempered scales.[43] According to Ellis, the British committee neglected the effects of temperament on tuning, which led to some embarrassing mistakes. For example, while they chose *c′* 528, they also chose the Scheibler/Stuttgart pitch *a′* 440. But with equal temperament, which recall was gradually being adopted by fixed-tone instruments by the time of the meeting, *a′* 440 yields an equally tempered *c′* 523, whereas *c′* 528 requires an equally tempered *a′* 444.[44] While the French Commission went for a compromise pitch, the British sacrificed practicality for a utopic, mathematical purity. As a result of this sharpening, augmented by measuring errors made by the maker of the tuning forks, Griesbach, 444 became 446 and equally tempered *c′* became 534, the British pitches were among the sharpest in Europe. The British Society of Arts' pitch became absorbed into the higher pitches in general, so that the *diapason normal* was the only recognized compromise pitch.[45]

A number of German court theaters (mostly those in the western territories, such as in Cologne and Stuttgart) adopted the *diapason normal*, but its acceptance certainly was not universal.[46] The Dresden singing master Karl Näke claimed in 1862 that there were areas throughout Germany that were strongly opposed to the pitch.[47] He personally launched a crusade against the French pitch, arguing that it was still too high for vocalists, causing harm to their voices. He accused the French Commission of pandering to instrument makers while ignoring the *Kapellmeister*, voice instructors, and singers themselves.[48] He was one of the first to draw a causal link between the increase in pitch and the decrease in singers' ranges. Voices were strained so much hitting the higher notes that they lost their power to sing at the extreme ranges, both upper and lower.[49] He feared that vocal instructors would now spend all of their time teaching their students to read higher pitches, while "worrying little about the beauty, richness and uniformity of the [singing] organ."[50] For Näke, pitch should be set neither by physicists nor instrumentalists, nor instrument makers. Rather the *vox humana* and historically determined pristine pitches were the arbiters of beauty. The Berlin music critic Otto Gumprecht concurred, writing in the *Berliner Nationalzeitung* on 22 November 1861, "the petition for the lowering of the concert pitch, if possible lower than the French standard, should by the way be the 'ceterum censeo' of all opera departments. The way things presently stand, not only will all collective voices, particularly the tenors, reach an early grave, but most musical scores in our classic operas will lose their original character."[51]

According to Näke, "the only true utility of the Parisian Commission are the measurements of the various older and current pitches from various locations."[52] His goal as *Gesangmeister* was to

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43 Ibid.
44 Ibid.
45 Ibid.
46 Ibid., p. 312.
47 Näke, *Ueber Orchesterstimmung*, p. 4.
48 Ibid., p. 3.
49 Ibid., p. 8.
50 Ibid., p. 9.
51 As quoted in ibid., p. 10.
52 Ibid., p. 5.

recreate the pitch used during Wolfgang Amadeus Mozart's life. With Scheibler's method of tuning in hand to ascertain this historical pitch, he claimed that it was the only true one for vocal works. His nostalgic reverence (and indeed worship) of Mozart was clear: "Add to this the piety for Mozart's works, the wish to hear his works unadulterated, as he himself heard them" should be the goal of establishing performance pitch.[53] He did his utmost to lower Dresden's musical pitch. According to the late nineteenth-century acoustician Alexander Ellis, Dresden was the only city in Europe whose city theater possessed two distinct sets of instruments tuned to two different pitches independent of the new French standard. The lower one was the mean pitch somewhere between 418 and 424 vps. The higher pitch was the Stuttgart/Scheibler pitch of 440.[54] In September 1862 a number of musicians, composers, and instrument makers gathered to test which pitch was better suited to opera.

Although apparently the French pitch held rather steadily for a quarter of a century, it failed, however, to become accepted as a universal standard, as pitches once again began to rise throughout Europe. After German unification in 1871, calls rang out for a national pitch. Pitch was, once again, rising, eclipsing the French *diapason normal*. The fear of high pitches destroying voices prematurely was, once again, raised, and many string-instrument players felt that the higher pitches favored woodwinds and horns.[55] Orchestras and bands needed to purchase fixed-tone instruments from manufacturers, which produced instruments at the requisite pitch. Again, although it might be in the financial interest of larger musical-instrument manufacturers to unite on a national pitch with concert and theater bands, instrument makers satisfied with a smaller market, particularly a number of piano manufacturers, often built their instruments in two pitches, a higher and a lower, and they were not about to make it three. And these manufacturers were often bitter rivals, not interested in collaborations. Apparently singers, directors, and band musicians still fought bitterly over what pitch would be most aesthetically pleasing.[56] A plea addressed to *Reichskanzler* Otto von Bismarck for a national pitch was published in the relatively new *Zeitschrift für Instrumentenbau*. The petition, signed by hundreds of instrument makers (including Schiedmayer & Söhne, renowned piano manufacturers of Stuttgart), music directors, composers (including Johannes Brahms), theater directors, opera singers, and musicians, formally requested Bismarck to create a Ministerial Commission comprised of acousticians, conductors, and instrument makers.[57] The petition's endorsers hoped that this commission would either accept the *diapason normal*, or accept Scheibler's *Normalton* of 440, since many felt that the French pitch was too low.[58] The petition concluded by asserting that "the introduction of a general standard pitch in all of Germany is so easy, and it accords all of the artistes as well as instrument manufacturers the greatest utility and advantage as well as the courage to attain this goal. We must feel ashamed in the company of foreigners if we persist in the hitherto differences in pitch."[59]

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53 Ibid., p. 6.
54 Ellis, "On the History of Musical Pitch," p. 312. The higher pitch was actually later measured to be 438.9.
55 Anon., "Aufruf zur Einführung einer allgemeinen Normalstimmung in Deutschland," *Zeitschrift für Instrumentenbau* 4 (1884), pp. 363-366, here p. 364.
56 Anon., "Aufruf zur Einführung einer allgemeinen Normalstimmung in Deutschland," p. 364.
57 The list was published in Anon., "Unsere Petition," *Zeitschrift für Instrumentenbau* 4 (1884/1885), pp. 427-429.
58 Anon., "Aufruf zur Einführung einer allgemeinen Normalstimmung in Deutschland," pp. 363-366.
59 Ibid., p. 366.

Although Bismarck never responded, from 16 to 19 November 1885 delegates from six nations met in Vienna to establish, for the first time, an international standard pitch. Austria, the host nation, had the largest contingent, including a number of luminaries: the leading musicologist of the period, Eduard Hanslick; composer and Minister of Education and Culture, Carl Zeller; the composer and General Secretary of the Conservatory of the *Gesellschaft der Musikfreunde*, Leopold Alexander Zellner; and University of Vienna's Professor of Physics and Director of the Institute for Experimental Physics, Josef Stefan, who served as the International Conference's President. Italy also sent a physicist, the University of Rome's Professor of Experimental Physics and Director of the Physics Institute, Pietro Blaserna, as well as the composer Giuseppi Verdi. Hungary, Sweden, and Russia all sent delegates as did Germany, from the cities of Berlin, Dresden, and Stuttgart.[60] France, which would go on to use the *diapason normal* regardless of what this International Conference decided, did not attend.

Apparently, the choice at the International Vienna Meeting was between two options: the *diapason normal* and the Italian pitch of *a'* 432 (corresponding to *b flat'* of 456). The Scheibler/ Stuttgart pitch of 440 was not an option. The most passionate advocate of the Italian pitch had been the Belgian physicist Charles Meerens, who was fundamentally committed to basing music theory and practice on the solid ground of mathematics.[61] Meerens, the son of a flautist and himself an amateur cellist, had traveled to Brussels in 1855 to study music; however, he had decided to turn his attention to acoustics. His first criticism of the *diapason normal* had appeared in his *Instruction élémentaire du calcul musical et philosophie de la musique* (Elementary Instruction of Musical Calculation and the Philosophy of Music) where he called the *diapason normal* of 435 an "unpardonable consequence" of the French Commission.[62] The argument Meerens had employed against the chosen concert pitch owed much to Chladni's reasoning. He argued that 432 could be divided by two (representing the octaves of *a'*) for four octaves, or the lowest range of human hearing.[63] And his *a'* of 432, which he called, "the correct concert pitch," corresponded to a just tuned *c'* of 256, which was 2 to the eighth power, a perfect geometrical ratio.[64] Mathematical calculations of the octaves were therefore easier, since fractional pitches were not necessary. Also, tuning forks of whole numbers were more accurate than attempts at producing those with fractional pitches.[65] More important for Meerens, it was the goal of applied science "in the domain of the arts [...] to point to anomalies of blind and arbitrary routine everywhere it is present in teaching."[66] Music merited a mathematical basis, not an arbitrary one. He continued, "In order

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60 Kaiserlich-Königliches Ministerium für Cultus und Unterricht (ed.), *Beschlüsse und Protokolle der Internationalen Stimmton-Conferenz in Wien 1885*, Vienna: Kaiserlich-Königlicher Schulbücher Verlag, 1885, pp. 3-4 and Sächsisches Hauptstaatsarchiv in Dresden, "Herbeiführung eines internationalen Stimmton's," Ministerium des Innern, 1885-1891, A. 847, Nr. 17537, folio 30.

61 See, for example, Meerens, *Instruction élémentaire du calcul musical et philosophie de la musique.* Meerens was drawing upon the work of Charles Delezenne, *Mémoire sur les valeurs numériques des notes de la gamme*, Lille: L. Danel, 1857 and idem, *Note sur le ton des orchestres et des orgues*, Lille: L. Danel, n.d., ca. 1850s.

62 Meerens, *Instruction élémentaire du calcul musical et philosophie de la musique*, p. 11.

63 If *a'* is 432, then *a* is 216, *A* is 103.

64 Charles Meerens, *Le tonomètre: d'aprés l'invention de Scheibler; Nouvelle démonstration a la portée de tout le monde*, Paris: Chez Colombier; Brussels: J.-B. Katto, 1895, p. 14.

65 Kaiserlich-Königliches Ministerium für Cultus und Unterricht, *Beschlüsse und Protokolle der Internationalen Stimmton-Conferenz in Wien 1885*, pp. 12 and 15.

66 Meerens, *Le Tonomètre*, p. 22.

to remedy this actual, upsetting situation of the question of the prototype of universal sound, it would suffice to rectify [this situation] by means of a simple line of a pen, which would lead to no material consequences, replacing the abnormal number of 870 V. [435 Hz] that figures in a few governmental decrees with the same correct number of 864 V. [432 Hz] so that the true and standard tuning fork becomes accepted throughout the world. Honor would be bestowed on the country that would take the initiative."[67] Meerens felt that the difference between 435 and 432 was so small that it was nearly imperceptible and therefore insignificant.[68] Long after the 1885 International Commission had endorsed the diapason normal, Meerens continued his assault, referring to the pitch as "abnormal,"[69] "absurd,"[70] "arbitrary,"[71] "incorrect," and "a hazard."[72]

Although the Austrian Commission appreciated "the scientific basis" (*wissenschaftliche Basis*) of the Italian pitch, they considered music to be a "practical" art (*praktische Kunst*).[73] Because the musical scale had been tempered since the time of Johann Sebastian Bach, it was not mathematically perfect. And, a tempered scale with *b'* at 456 would not yield a concert pitch *a'* of 432, but rather of 430.[74] The Commission decided that "we are called to find a fair settlement and a correct balance between the purely scientific (*wissenschaftlichen*) and practical standpoints in the interests of our art [...]."[75] If Austria were to view the standard pitch from only a scientific standpoint, Zeller continued, then clearly the Italian pitch would be more appropriate. The Austrians, however, decided that practicality was more important. And since the French pitch was in more common use than the Italian, the Austrian Commission decided, "despite the principle steadfastness of their [the representatives of the physical sciences] viewpoint," to vote for the French pitch.[76]

The Italian representatives then responded to Zeller's report. Blaserna recounted how the Italians at the Milan Congress of 1881 chose 432 for performance pitch, purely following a mathematical model.[77] Defending his nation's decision, he countered the French and Austrian's claim that practicality needed to rule the day by asserting that "the question of a tuning fork is not merely a musical question, but also a theoretical question."[78] *Pace* Meerens, Blaserna argued that the difference between 435 and 432 was so small as to be nearly imperceptible. And he added, the "scientific worth of the easier mathematical calculation and the resulting easier, more natural construction [of the tuning forks] and also the more straightforward teachings should be given preference."[79] Blaserna's compatriot, Maestro Arrigo Boito, echoed these sentiments. Drawing

67 Ibid.
68 Charles Meerens, *L'Avenir de la science musicale*, Brussels: J.-B. Katto, 1894, p. 10 and idem, *Acoustique musicale*, Brussels: J.-B. Katto, 1892, p. 56.
69 Meerens, *Acoustique musicale*, p. 56.
70 Ibid., p. 59.
71 Meerens, *Instruction élémentaire du calcul musical et philosophie de la musique*, p. 11.
72 Meerens, *L'Avenir de la science musicale*, p. 10.
73 Kaiserlich-Königliches Ministerium für Cultus und Unterricht, *Beschlüsse und Protokolle der Internationalen Stimmton-Conferenz in Wien 1885*, pp. 13-14.
74 Ibid., p. 14.
75 Ibid.
76 Ibid.
77 Meerens lauded Blaserna's efforts. See Meerens, *Acoustique musicale*, p. 59.
78 Kaiserlich-Königliches Ministerium für Cultus und Unterricht, *Beschlüsse und Protokolle der Internationalen Stimmton-Conferenz in Wien 1885*, p. 15.
79 Ibid.

upon the theoretical works of Meerens, he wished to draw the Commission's attention to the dangers of ignoring the scientific relevance of musical pitch. "Our century is totally turned to the sun of science. The rays of this sun warm through and penetrate all disciplines of human knowledge, even also art. Wanting to avoid the influences of this on us in the surrounding atmosphere, and instead of choosing the scientifically preferred tuning fork, we choose 435, we would be committing a type of anachronism."[80] Two Prussian delegates, Martin Blumner and Franz Wüllner, disagreed with the Italians, and spoke in support of the French pitch. Max Seifriz expressed concern of the cost of manufacturing new instruments to even lower pitches. Pers Jonas Fredrik Vilhelm Svedbom also chimed in supporting the *diapason normal*.[81]

The physicist Stefan proffered his own view. If science were to dictate the determination of performance pitch, he would be obliged as a physicist to choose 432: "The number 864 [simple vibrations, or 432 Hz] possesses the only advantage of an arithmetic aesthetic (*arithmetische Ästhetik*)."[82] Since the *diapason normal* was being used in France, Belgium, Russia, and in a number of German and Austrian institutions, he supported the French pitch.

The meetings concluded for the day, resuming discussion on 17 November. General Secretary Leopold Alexander Zellner thought it best to draft a proposal arguing that while 432 had considerable advantages for the theory and practice of music, the French tuning fork should be accepted as an international standard because of its popularity throughout Europe.[83] The Prussian Joseph Joachim, however, disagreed. Both he and the Austrian musicologist Hanslick feared that by stating one pitch is better than another for certain cases, the international pitch would most likely not be as readily accepted and enforced.[84] After further discussion and debate, Boito and Blaserna acquiesced, and the French *diapason normal* was chosen as the official international performing pitch.[85]

Although the "scientific" pitch did not win out, it would be a mistake to assume that physical science did not play an important role in the new standard. The members of the conference all agreed that the standard pitch needed to be constructed according to scientific rules. The fork needed to produce 435.0 vibrations per second at 15°C.[86] In order to guard against changes in the standard pitch, each country was to select an office, which would be responsible for generating tuning forks with the correct pitch. The fork was to be made from unhardened cast steel, and the prongs had to be parallel and at least one-half centimeter in width.[87] The fork clearly need to be rust-free and polished white hot or tempered blue.[88]

Blaserna and Stefan drew upon their expertise to advise the other members of the conference on the physics of tuning forks in order to ensure the fidelity of the original and replica forks. Blaserna noted how the effects of temperature, both room temperature and the heating of wind instruments from the constant breath of the performer, had not yet been sufficiently researched. Tuning forks were less influenced by heat than musical instruments. Blaserna argued that a

80 Ibid., p. 16.
81 Ibid.
82 Ibid.
83 Ibid., p. 18.
84 Ibid.
85 Ibid., pp. 19-20.
86 Ibid., p. 20.
87 Ibid., p. 24.
88 Ibid., p. 25.

difference in temperature of 30°C would change the vibrations by three-quarters of a complete vibration per second. The pitch of an organ pipe, however, was much more dependent on the temperature. Earlier studies had indicated that a pipe that sounded at 435 vps at 15°C increased in pitch to 457.7 vps at 30°C, nearly a semitone higher.[89] Stefan, supporting Blaserna's comments, informed his colleagues that the number of vibrations of a metal rod, such as a tuning fork, will lose one half of a complete vibration with an increase in temperature of 10°C, whereas the number of vibrations of an air column, such as an organ pipe, will gain eight complete vibrations per second with the same increase in temperature.[90] This emphasis on precision was precisely what the conference delegates desired. They voted to use an electromagnetically powered tuning fork to tune orchestras. Tuning to the oboe, which had been the preferred method of tuning an orchestra, was now to be used only when no tuning fork was available.

Stefan offered his technical and scientific expertise by recommending how the standard tuning fork should be constructed. He enjoyed the reputation of being Austria's foremost experimental physicist. His most important work had been completed in 1879, when he determined that heat radiation is proportional to the fourth power of the absolute temperature. Ludwig Boltzmann theoretically deduced this relationship, which is exact only for black bodies, known as the Stefan-Boltzmann law of radiation. Stefan also worked on heat conduction in gases, devising a diathermometer used to measure heat conduction of clothing. And, he contributed works on the kinetic theory of heat, heat conduction in fluids, the relationship between surface tension and evaporation and acoustics.[91]

Stefan argued that first and foremost the standard tuning fork needed to produce 435 vibrations per second at 15°C, as set by the conference. The number of the fork's vibrations should not change over time, and they should sound for a relatively long period after being struck. Finally, the tuning fork should be suited for the experimental optical method, an earlier version of which was pioneered by Lissajous.[92]

The constancy of the number of vibrations of a tuning fork was predicated on the stability of its mass, form, and elasticity. The correct mass and form could be assured by using a material of great hardness and elasticity, such as cast steel. The tuning fork needed to be gold plated in order to prevent a change in mass due to oxidation. Stefan postulated that heavy use of tuning forks would damage their elasticity, thereby affecting their pitch. He therefore suggested producing two forks, one standard fork rarely used and the other tuned in unison to be used for tuning musical instruments and conducting physical experiments. This second fork would be periodically compared to the standard fork to check its fidelity.[93]

In order to ensure that the tuning fork would continue to sound well after its being struck, Stefan argued that its prongs needed to have the same length, width, and thickness. They also needed to be absolutely parallel and separated further apart than the tuning forks from earlier periods. Older tuning forks made during the 1820s and 30s – those for example used by Wilhelm

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89 Ibid., p. 25.
90 Ibid.
91 Walter Böhm, "Josef Stefan," in: Charles Coulston Gillispie (ed.), *Dictionary of Scientific Biography*, vol. 13, New York: Scribner, 1976, pp. 10-11.
92 Kaiserlich-Königliches Ministerium für Cultus und Unterricht, *Beschlüsse und Protokolle der Internationalen Stimmton-Conferenz in Wien 1885*, p. 37.
93 Ibid., p. 38.

Weber – had their prongs relatively close together such that a decrease in amplitude lead to an increase in pitch. Stefan suggested drawing upon the work of the artisan Rudolph Koenig.[94]

Lissajous' optical method, used to compare the pitches of two tuning forks, was ideal for the standard tuning fork. The ends of the outside of the prongs needed to be totally flat and reflecting from at least one centimeter from the edge upwards. Stefan recommended against using separate mirrors attached to the forks – as Lissajous had initially employed –, since the extra weight could slightly change the fork's pitch. It was sufficient for the fork to have an extremely lustrous point that could be seen through a vibrating microscope. This setup in combination with a tuning-fork clock constructed by Koenig, Stefan argued, was the simplest method known to determine the fork's number of vibrations.[95] Stefan recommended that one use Koenig's tuning forks, as they were constructed with "extreme precision."[96]

After relying on science for state-of-the-art precision measurement, the conference members took steps to guarantee that the standard pitch would indeed be internationally recognized and enforced. They strongly suggested that the pitch be used in public and private schools where music was taught, as well as musical associations and theaters. Military bands, particularly guilty of sharpening the performance pitch over the previous half century, were to adopt the pitch as soon as possible, or at the very latest, at the time of the next restorations of the woodwinds. Churches, too, were to restore their organs to the pitch as soon as was feasible, or at the next organ repair. Each country was to set its own time limit for these changes. Instrument makers were initially instructed to tune their musical instruments to the *diapason normal* at 24°C, but the temperature was then lowered to 20°C, closer to the officially tuned tuning fork of 435 Hz at 15°C.[97]

In Germany the governmental institution responsible for overseeing the production of new tuning forks was the Technical Section of the renowned *Physikalisch-Technische Reichsanstalt* (henceforth PTR). Leopold Loewenherz, the section's director, reckoned that an agreement on a unified pitch was just as important to the practice of music and the production of musical instruments as the determination of a standard weight and mass was for commerce. Although the recommendations for a standard pitch had dated back to the seventeenth century, Loewenherz underscored that Scheibler's *a'*, to which Loewenherz referred as the German pitch, was approved by the *Versammlung deutscher Naturforscher und Aerzte* in Stuttgart in 1834.[98] Alas, the *Versammlung* lacked the political clout to implement its standard. Lamenting the *Versammlung*'s impotence, he rather sarcastically remarked that "regretably, France has taken this step [in determining its *diapason normal*] without coming to an understanding with the other major cultural nations."[99] He also criticized the Vienna Conference's decision to accept the pitch notation in dvps, or 870 dvps, rather than 435 vps. One notes, once again, the rhetoric of anti-French sentiment emerging in Loewenherz's essay:

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94 Ibid.
95 Ibid., p. 39.
96 Ibid., p. 40.
97 Ibid., pp. 20-24, 28, and 30.
98 L[eopold] Loewenherz, "Ueber die Herstellung von Stimmgabeln," *Zeitschrift für Instrumentenkunde* 8 (1888), pp. 261-267, here p. 261.
99 Ibid.

> Then not to mention that by far the most influential acoustical examinations have stemmed from these [German and British] researchers [who use vps, rather than dvps], the French method of counting cannot be applied to vibrations of a sounding air column, such as those occurring in wind instruments and in singing. The pitch, which a pipe generates when it executes 435 vibrations against the reed in one second, is equally as high as the pitch of a tuning fork, which produces 435 vibrations in one second, using the German method of counting. In addition, the most straightforward method to compare two tuning forks possessing pitches close to each other is to determine the number of vibrations, i.e., the alternating rise and fall of the pitch, which is heard in one second with the simultaneous sounding of both forks. This number immediately gives the difference of the number of vibrations according to the German method of counting.[100]

He was also rather critical of the Commission's choice of the temperature for the *diapason normal*, 15°C, since concert halls and theaters were generally warmer, particularly during the summer months. Finally, the creation of a standard tuning fork, in Loewenherz's eyes, was "superfluous" and "unnecessary": superfluous, because the physical methods in connection with a good astronomical clock offer the means at any time to determine the number of vibrations a fork with sufficient precision, and unnecessary, because with the well-known nature of steel, a change in the number of vibrations with time is very probable.[101] These reservations notwithstanding Loewenherz realized that German mechanics needed to produce tuning forks, which followed the Vienna's Commission specifications. Forks needed to be produced from one piece of steel and had to be totally symmetric. Both prongs should be prismatic in shape and possess precisely the same perpendicular cross sections. The inner portion of the yolk should be semicircular. The breadth of the prongs (i.e. the side of its cross section in the profile of the fork) needed to be at least 5 mm. The prongs could not be thinner than 2.5 mm. And, the greater the mass of the fork, the fuller the tone. The Vienna Commission recommended that the tuning fork be attached to a resonance box and stimulated by an electromagnetic current. This recommendation, however, was impractical, as the pitch of the fork changes with the strength of the current. And, concertmasters could not be expected to use such physical methods. Hence, Loewenherz suggested that one simply bow the fork, which was attached to a resonating box, with a cello or violin bow several times. One repeats the bowing once the fork begins to weaken in volume, which usually happened after twenty seconds.[102] If bowing failed to produce a full, rich tone, Loewenherz recommended that one gently hit one of the prongs with the wooden portion of the bow. He also suggested that each orchestra's tuning fork be tested every two years. He urged German mechanics to pay more attention to the production of tuning forks than they had previously done.[103]

The PTR recommended three different types of tuning forks. The first was the shape of Rudolph Koenig's tuning fork, in which all the cross sections of the prongs and the yolks were at right angles (fig. 1 in fig. 6). The base was round and tapered off to a screw, which could be attached to a resonance box. Each prong was approximately 5.5 mm thick and 14 mm wide. The second type of the tuning fork was suggested by Wolter of Vienna (fig. 2 in fig. 6). It basically had the same shape as Koenig's, but was a bit smaller, with the prongs 4 mm thick and 9 mm wide. The

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[100] Ibid., p. 263.
[101] Ibid.
[102] Ibid., pp. 263-264.
[103] Ibid., p. 265.

third type was the style chosen by the Berlin mechanic Reichel (fig. 3 in fig. 6). It was particularly well suited for hand use, and its pattern was based on the tuning forks of German military bands. Both prongs were separated by merely 2 mm; as a result, the fork's pitch sounded for a much longer period of time.[104]

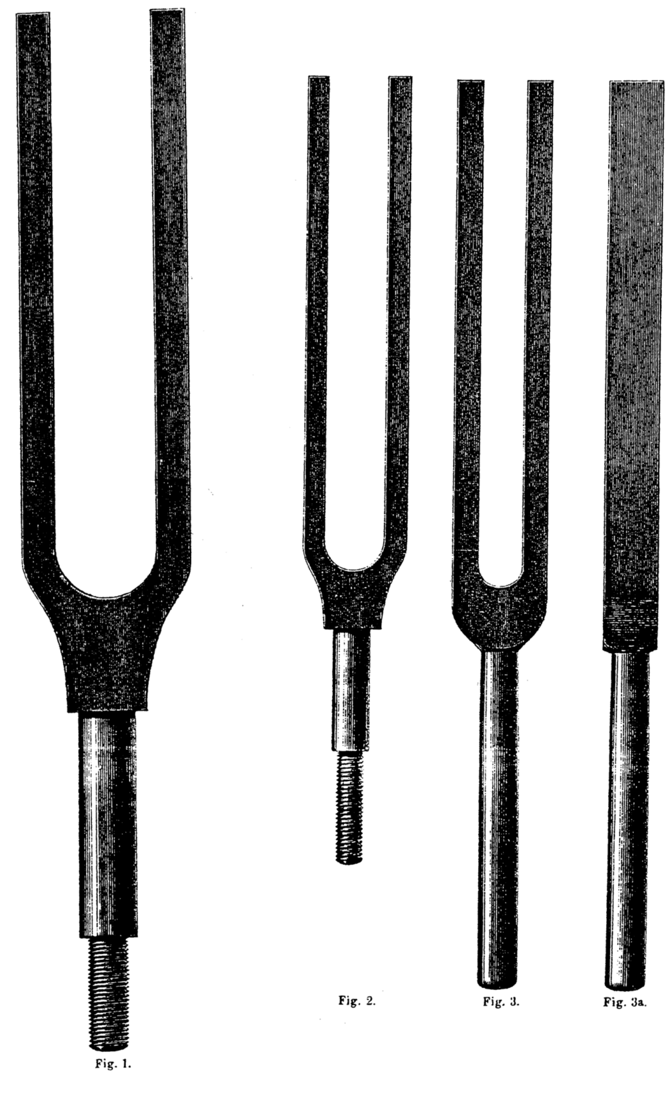

Fig. 6: Three tuning forks recommendeed for determining concert pitch by the Physikalisch-Technische Reichsanstalt in 1888. From: L[eopold] Loewenherz, "Ueber die Herstellung von Stimmgablen," *Zeitschrift für Instrumentenkunde* 8 (1888), pp. 261-267, here p. 263-264.

In order to tune the forks to the desired pitch, Loewenherz recommended the following method: one used two tuning forks, which were 1 vps sharper and flatter than the fork to be tuned. Strike the fork to be tuned together with the higher-pitch fork: one can hear that they will produce one beat per second. Repeat the process with the lower-pitch fork and the fork to be tuned, and one should once again count one beat per second. If this is so, the fork is perfectly in tune. If the fork

[104] Ibid., pp. 265-266.

is too sharp, then one files the inner side of the yolk. If the pitch is too low, then the prongs' ends need to be filed down.[105] In 1889 Hermann von Helmholtz summarized the PTR's procedure for testing tuning forks.[106]

The need for the manufacture of precise, reliable tuning forks for music institutes raised important questions for mechanicians and physicists on the accurate measurement of pitch. In 1883 Reichel had reported that the pitch of tuning forks could not be accurately determined by using a monochord. He recommended an electromagnetically powered tuning fork with a small pin dipped in ink on the end of one of its prongs. That tuning fork would be struck by a mallet, and the pin would graph vibrations on a rapidly revolving cylinder, and the waves would be counted.[107] This procedure was referred to as the graphic method of determining the frequency of a tuning fork. In 1890 Leman summarized the various methods the PTR was using for determining the pitch of sounding bodies, commenting on their advantages and disadvantages. He discussed the graphic method of calculating frequency, Koenig's tuning-fork clock, and von Lang's method of the Hipp chronoscope, a timing device powered by a weight hanging under the clockwork mechanism. Two dials indicated the time in seconds and tenths of seconds. The mechanism was controlled by a pair of electromagnets. The device was used to time short elapsed intervals in reaction-time experiments, and therefore was often used in psychological experiments. Leman also included a discussion of Scheibler's tonometer; Heinrich Appun's sonometer comprised of reed pipes (rather than tuning forks); the various siren designs of August Seebeck, Félix Savart, and Cagniard de la Tour; Poul La Cour's phonic wheel, and Lord Rayleigh's method.[108]

In conclusion, debates about the standardization of beat and pitch raged throughout the nineteenth century. Should the art form of music be subjugated by mechanical standards? And how precise should those standards really be? Although I concur with Haynes that, for the case of pitch in particular, the precision offered by physicists was far greater than was necessary, one must not therefore neglect the role that physicists and mechanics played, as musicians viewed them as the arbiters of precision and standardization. Physicists and mechanics actively contributed to debates on what concert pitch should be and how it could be measured. But the flow of knowledge and skill was not unidirectional. The need to come up with ways to produce and test new tuning forks resulted in new investigations by physicists and mechanics, as they grappled with their own questions of precision, accuracy, and reliability in the laboratory. The study of standardization also illustrates the role of science in determining aesthetic parameters. Whether or not pitch should be based on a mathematical-physical notion of aesthetics, or on a practical notion of performance, or on a nostalgic, historical basis was hotly contested throughout the nineteenth century. And the effects of its eventual resolution rippled throughout various European economies, nationalistic sentiments, musical-instrument manufacture, and acoustical research.

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[105] Ibid., p. 266.

[106] Hermann von Helmholtz, "Kleinere (Original-) Mittheilungen: Bestimmungen über die Prüfung und Beglaubigung von Stimmgabeln," *Zeitschrift für Instrumentenkunde* 9 (1889), pp. 65-67.

[107] C. Reichel, "Ueber die Justirung der Stimmgabeln auf genau vorgeschriebene Schwingungszahlen," *Zeitschrift für Instrumentenkunde* 3 (1883), pp. 47-51.

[108] A. Leman, "Ueber die Normalstimmgabel der Physikalisch-Technischen Reichsanstalt und die absolute Zählung ihrer Schwingungen," *Zeitschrift für Instrumentenkunde* 10 (1890), pp. 77-87, 170-183, and 197-202.