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CHAPTER 7

A GRAY BOX: THE PHONOGRAPH IN LABORATORY EXPERIMENTS AND FIELDWORK, 1900–1920

JULIA KURSELL

INTRODUCTION

IN 1878, the year after Thomas Alva Edison submitted the first patent for his phonograph, two British physicists, Fleeming Jenking and J. Alfred Ewing, published a report in the scientific journal *Nature* of a recent experiment they had conducted. This experiment used Edison's device to address the nature of spoken language:

> Let a set of vowel sounds, as A E I O U (pronounced in Italian fashion), be spoken to the phonograph in any pitch and with the barrel of the instrument

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> turned at a definite rate. Then let the phonograph be made to speak them, first at the same rate, and then at a much higher or lower speed. The pitch is, of course, altered, but the vowel sounds retain their quality. (Jenkin and Ewing 1878, 384)

As Jenkin and Ewing noticed, the faster or slower speed of the phonograph altered the pitch of the vowels, making them appear to be spoken by a higher or lower voice. Yet, they found the quality of the voice remained the same: They could still recognize the recorded vowels. This experiment was soon contested. Charles Cross, working in Boston, challenged these findings with his own experiments using one of the first prototypes of the phonograph built by Edison. Cross (1878), in a reply that was also published in *Nature*, asserted that a change in speed actually distorted the vowels to the extent of making them unintelligible. For Jenkin and Ewing, however, their experiment had a second purpose, one that is easily overlooked. Most of their report was devoted to the reconstruction of "the instrument." Unlike Cross, they did not have access to the instruments Edison had built himself. For Jenkin and Ewing it was therefore a major concern whether they would manage to construct the phonograph at all based on the inventor's description. They struggled with every aspect of the complicated apparatus, such as finding a foil that would allow the recorded sound to be replayed more than once and making a spring that would not only hold the speed of the barrel constant but also allow for controlled deviation. Such concerns are part and parcel of laboratory work and the well-known difficulty in replicating pioneering experiments (Collins 1985). Their article also demonstrates that they understood the phonograph to be a scientific instrument whose technical functions had yet to be defined. The mass production of phonographs, either for the laboratory or for commercial purposes, had not yet occurred.

Some twenty years later, a group of experimental psychologists, based at the Berlin Institute of Psychology, started to integrate the phonograph into their scientific work on a systematic basis. In 1900 Carl Stumpf, founder of the institute and its director until 1921, recorded a Siamese court theater group on twenty wax cylinders. These recordings laid the foundation for what was to become the Berlin Phonogram Archive. In 1908, when the existence of this archive was officially announced, the collection contained more than one thousand items—the number of phonographic rolls would eventually grow to thirty thousand.

In 1901 Stumpf extensively discussed his first recordings in the institute's journal, *Beiträge zur Akustik und Musikwissenschaft*. Summing up, he touched upon the issue of methodology. In order to preserve samples of music that were as yet unknown to researchers and were in danger of being lost forever, a double strategy was recommended. Traditional notation, though necessary for discussion within the scientific community, was not sufficient but had to be backed up by phonographic recordings (Bruynincks, this volume). However, Stumpf was well aware of the difficulties posed by phonographic recordings. Among the major problems he listed was the recording speed: "Most importantly, one has to provide for constant rotation speed . . . The difficulty lies in . . . avoiding the troubles caused by arbitrary diminishing of the rotation speed, as this will produce sounds that are too low and tend to blur" (Stumpf 1901, 135–6).

Twenty-five years later, in 1926, Stumpf summed up his research of the past two decades in a treatise on the sounds of language, titled *Die Sprachlaute* (1926). One chapter was devoted to phonographic experiments with vowels. The initial question that had driven Jenkin and Ewing to reconstruct the phonograph had since been solved, Stumpf declared. It was now agreed that reproducing recorded vowels at a different speeds would alter their sound. This was because the characteristic sound of the vowels resulted from resonances that depended on the shape of the mouth cavity. The pitch of these so-called formants was fixed. A change in the rotation speed would thus alter the pitch of the recorded resonance frequencies and therefore distort the vowels' characteristics.

Stumpf's very detailed experiments, however, did more than just provide yet another verification of this already accepted theory. As his report demonstrates, even by 1926, when wire recording had started to replace it as a recording device, many aspects of the use of the phonograph were still in need of careful study. The phonograph thus appears as a site of intersection for technology, experimental practices, and ways of hearing and listening, none of which were stable. Rather, they continually changed in the course of the experimental work, and the means of recording and the means of listening were constantly adjusted in relation to each other. Practices of fieldwork involving phonographs, tests in the laboratory, and the organization of storage and access in the phonogram archive were finely tuned to each other. For their experiments, psychologists developed technologies for the production of multiple copies and standards for identifying the rotation speed. They tested the degree of variation in recording quality, and they eventually discovered the interrelatedness of ways of recording and ways of listening.

Among the thirty thousand wax cylinders preserved in the Berlin Phonogram Archive today, with musical recordings from all over the world, there are also several items made for experimental use. These "experimental cylinders" (*Experimentalwalzen*), as they are classified in the lists of the archive (Ziegler 2006), are the focus of this chapter.[1] They show that the phonograph was not just a new apparatus ready at hand. Rather, experimental work was needed to create uses of the phonograph, to gauge its products (the wax cylinders), and ultimately to enable recurrence and comparison as the basic operations of the phonogram archive. Tracing the history of the phonograph means tracing the "becoming" of a medium.

Eight of the experimental wax cylinders were used to study the tone color of vowels. Taking this series of experiments as an example, my chapter addresses the following: First, I show that a medium is not a given entity but rather an unstable and heterogeneous object. In the 1980s, German media studies borrowed Michel Foucault's notion of the "historical *a priori*" (Foucault 1969) to analyze discourses of media culture. Most prominently, Friedrich Kittler transformed "historical *a priori*" into "technological *a priori*" and discussed how "discourse networks" grow from new technologies (Kittler 1990, 1999). By showing how media produce inscriptions, such analyses investigated the way in which technologies selected and shaped the utterances possible in a network by forcing communication into specific formats.

To be sure, sound recording, as made possible by the phonograph, can be said to have created such a discursive network. On the one hand, the phonograph immediately suggested new ways of asking questions even though none of its material aspects were yet fixed. On the other hand, some level of technical reliability and established modes of use made it possible to study the phonograph itself, turning it from a technical object into an object of investigation (Rheinberger 1997). There is thus an inherent ambiguity in the use of a medium, seen in the process of its emergence. While in the beginning, the phonograph was immediately accepted as a scientific instrument, the commercial use soon dominated, turning the phonograph into something completely different. Scientists, however, did not stop using the phonograph but rather integrated its new functions into their own work. This chapter traces this ambiguity, looking at the emergence of the Phonogram Archive in Berlin. More specifically, I show that the researchers had to adjust, calibrate, and standardize the new functions again before integrating them into the scientific context.

I thus propose a view of the complex history of sound as it moves through the laboratory. Science and technology studies (STS) offer the framing for a history of media that can accommodate the idea of change and allow for the analysis of the phonograph as a site of intersections between its various uses.

Instruments

In 1878 Edison's phonograph entered the scientific community. Experimenters such as Jenkin, Ewing, and Cross were by no means unprepared to accept this new instrument. "Self-recording instruments" had had a role in the laboratories of the life sciences since the 1840s, when the "kymograph" was invented; sound recording, though without a rendition of the graphically recorded pressure wave, soon became one of the kymograph's specific uses (Sterne & Akiyama, this volume). In his first report on this new device, Carl Ludwig included a sample of the resulting curves, showing traces of two bodily functions. The registration of blood pressure was paralleled by the registration of lung pressure for the same individual. Each of these movements had been traced onto the blackened surface of a turning cylinder at the same time. This simultaneous registration of two curves opened up the possibility of correlating body processes more generally, an effort numerous laboratory researchers engaged in during the second half of the nineteenth century.

It is easy to overlook the fact that what made this instrument so important was the correlation rather than the simple fact of recording. The success of the new recording method lay in its promise of mathematically formalizing the body's processes instead of merely visualizing them (de Chadarevian 1993). In later developments of the kymograph, this correlation became standard, although it was featured less and less on the visible surface of the graphic tracings. Soon after the kymograph was introduced, tuning forks were integrated into the apparatus (Jackson 2006 and this volume). Their regular vibration, registered in parallel with the observed body functions, served as an indicator for the speed of the turning cylinder. The shape of the tuning fork's curves enabled the observer to detect any irregularities occurring in the rotating movement. This new arrangement enabled the experimenters to register only one bodily function and then to correlate it with the time indicated by the fork. As the fork vibrated at, for instance, one hundred times per second, its curve related the observed body process indirectly to chronometric time. At this stage, the two elements necessary for correlation were still present in the shape of two registered curves. The function of reference was, in later kymographs, displaced by the supposed regularity of the cylinder's movement. The function of correlating eventually thus became part of the technical device. The tuning fork, which at first seemed to replace the registration of a second bodily function, turned out, with hindsight, to have been an externalized control device. After the tuning fork, its curve, and its soft humming disappeared from the assemblage, the function of control persisted but was internalized in the apparatus. The cylinder of the kymograph was now understood to represent a system of coordinates that allowed the curves to be read directly (i.e., as a visualization of the movement), which did not necessarily require mathematical calculation.

The phonograph posed a new challenge to laboratory work: Experimenters had to use their ears. Jenkin and Ewing carefully embedded this new task in the more common procedures of gauging and comparison. Their experiment on the recording speed was actually part of a larger project that consisted of two series of experiments. Their short announcement about vowel quality in 1878 was followed by several longer reports on extensive studies of vowel traces, in which the phonograph was seemingly understood as yet another device for producing visible traces. However, the traces were more difficult to obtain, as the authors explain:

> The experiments were made as follows:—The vowel under consideration was spoken or sung at a given pitch, determined by a piano, while the barrel of the phonograph was turned at a definite speed, regulated by means of a metronome. The indentations made in the tin-foil were then mechanically transcribed, so as to give curves representing a magnified section of the impressions. . . . All transcripts were rejected if the tin-foil did not continue to give the sound clearly after being used to produce these curves. (Jenkin and Ewing 1878, 340)

On first impression, hearing seems to be an addendum to a technique of visualization in these experiments, turning the visible recordings into authentic traces of sound. Like many researchers before them, Jenkin and Ewing produced curves that they hoped would explain the nature of sound. It seems here that the audio recordings functioned mainly to provide further verification of the data recorded in the curves. Indeed, the bulk of the experiments were dedicated to the analysis of curves. In this respect the two researchers continued what had been done with devices such as the phonautograph (Sterne and Akiyama, this volume). Similar to the many varieties of the kymograph—including the labiograph, laryngograph, or logograph, which recorded movements in vocal sound production and in the air—the phonautograph turned vibrations into a curve on blackened paper (Panconcelli-Calzia 1994; Rieger 2009).

The phonograph, however, shifted the focus to hearing. This was due, first, to technical constraints, as the tin foil was designed to carry only the traces of the sounds. No other (i.e., visual) inscription could be made in that same medium. Second, this forced the experimenters to carry out various functions of adjusting, calibrating, and controlling the correct operation of the phonograph with their ears. Hearing was required both for comparing the pitch of the recorded sound to some given instrument and for controlling the speed of the barrel by means of a metronome. Listening to the recorded sounds after they had been mechanically transformed into a shape was supposed to guarantee that the indentations still referred to the same sounds. Instead of correlating two simultaneously recorded processes, another mode of correlating was now developed that involved the sense of hearing. It successively addressed different—visual and audible—recordings of the same process rather than correlating simultaneous recordings of different processes.

The new way of producing data—data that in fact served as a token for listening—remained almost imperceptible as long as the main method of correlation still involved the familiar analysis of visible curves. In the experiments on the distortion of vowels, however, the correlation of what was actually heard during the experiment came to the fore. Perhaps the most important shift between these experiments and Jenkin and Ewing's later work was the following: A change of speed was applied to recordings. Thus, correlation now applied to audible data alone. The issue at stake here was not comparison between nature and recording but the transformation of recorded sound itself.

Vowels

The phonograph enabled experimenters to answer a still-unresolved question about the nature of sound. Scientific investigations in sound color did not begin in earnest until the nineteenth century, although already in 1761 Leonard Euler critically remarked in one of his *Letters to a Young German Princess* that the timbre of tones had escaped the attention of philosophers. As he explained to his addressee, listeners easily discriminated the loudness of tones. Also, music had taught them that tones vary in pitch, and it is on this differentiation that musical harmony was based. There was, however, another property of sounds that people often experienced when listening to music: "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" (Euler 1823, vol. 2, 68). The human voice, "that astonishing master-piece of the Creator" (69), 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 it should be possible to construct a machine that could articulate the sounds of language: "The thing does not seem to me impossible" (70).

Subsequently, various attempts were made to construct such a device.[2] In 1780 Danish physician and physicist Christian Gottlieb Kratzenstein won a prize awarded by the Imperial Academy of Saint Petersburg for the successful construction of organ pipes that could imitate the vowels of language (Ungeheuer 1983, 157). Wolfgang von Kempelen constructed a talking machine around 1780, an apparatus that emitted entire phrases in various languages. In this machine, bellows sent air through a variety of devices that would perform different aspects of articulation, such as phonation and the formation of vowels and sonorous and noisy consonants. In the final stage, the air passed through a malleable leather bell whose shape could be changed by hand, thus altering the quality of the "vowel" sounds (Kempelen 1791). 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, however, was a by-product 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. 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 may appear, can never, I contend, lead to any accurate knowledge of the subject. (Willis 1830, 233)

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 broke completely with the idea of such similarity. While the article is mostly about air columns in reed pipes, this one experiment did not involve any wind instrument. Holding a piece of watch spring against a revolving toothed wheel, an alternation of sound qualities was produced that depended on the length of the vibrating portion of the spring. As Willis observed:

> 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. (249–50)

Some thirty years later, Helmholtz reported on this experiment to strengthen his own argument that sound color is independent of a particular sound source. Singling out Willis's experiment as the one in which the similarity of sound sources was most clearly abandoned, he remained critical: "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" (Helmholtz 1885, 118).

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 (Jackson, this volume). In reed pipes, a stream of air that is regularly interrupted produces the tone. An opening that opens and closes cuts the airstream 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 included not only 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, Helmholtz 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 these "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.

Helmholtz's further investigation of vowels as sound colors divided acousticians into two groups. In the late 1850s he had started publishing his first experiments on the sound color of vowels (Helmholtz 1859). The main impulse for taking up this question was a mathematical theorem originally proposed by Jean-Baptiste Joseph Fourier at the beginning of the nineteenth century. It claimed that any periodic wave could be formally described by its sinusoidal components. Building upon prior assumptions by Georg Simon Ohm, Helmholtz applied this theorem to the periodic waves of musical tones. He claimed that if Fourier's theorem applied to these components of a tone, it predetermined the relationship of the components as forming integer ratios.

The sound color of vowels served as Helmholtz's most prominent object of investigation. He was even able to synthesize a number of vowels from sinusoidal components that he obtained from a set of amplified tuning forks. The sounds of vowels fitted the experiment all too well. They built up a set of sounds that were easy to discriminate even when pronounced under the most varied conditions, such as speaking, singing, or whispering. As it turned out, they were also comparatively easy to synthesize. At first glance, their sound color seemed to be determined by the relative strengths of the different sinusoidal components. This was in keeping with the analysis of musical instruments that Helmholtz carried out. Specific patterns in the components, such as the relative strength of every other component in the series of overtones in the sounds made by a clarinet, made it likely that these patterns would reappear in every note the instrument was able to produce. The vowels Helmholtz synthesized revealed a similar pattern: for an *u* (pronounced in the German manner), only one component was enough; an *o* could be produced with two strong components, while reinforcing the third component in the row of tuning forks produced a sound more similar to an *a*. Vowels thus seemed an exemplary case for a study of sound color in general.

However, the analysis of vowels revealed something different from Helmholtz's findings on the sound of musical instruments. The characteristics of vowels depended not just on a relative pattern of strong components but also on the absolute pitch of one or more of the stronger components in the sound spectrum. This had gone unnoticed as long as the production of sounds was tied to the fixed pitch of the tuning forks. With tuning forks a modification of pitch was almost impossible. Yet, the two aspects of articulation rather easily explained this phenomenon, as the shape of the mouth did not change when a vowel was sung at different pitches. Therefore, the vocal cords alone produced the difference in pitch while the mouth alone produced the differences in sound color. Hence, Helmholtz inferred that vowels differed from musical instruments in that their characteristics involved an element of absolute pitch. For *e* and *i*, he even discovered two such elements that had been too high for his tuning fork synthesizer to produce.

Jenkin and Ewing immediately responded to the invention of the phonograph by seeing it as the device that would shed light on the question of the color of sounds. They perhaps understood the new possibilities for manipulating recordings that the phonograph offered before grasping the meaning of the phonograph as producing audible and manipulable tokens for acoustic research. They saw the phonograph as a laboratory instrument that would enable them to carry out the controlled transposition of frequencies. A change in the rotation speed would alter all recorded frequencies in the same way. In this respect, the phonograph actually resembled an existing acoustic apparatus: the siren (Jackson, this volume; Welsh 2008). This instrument consisted of a rotating perforated disc through which a stream of air was passed. When one of the openings in the disc crossed the airstream, the air could pass through the disc; thus, a regular series of air pulses emerged, which, starting at a certain frequency, were heard as tones. The typical howl of the siren was due to the fact that the rotation had to be started at zero velocity and reach the required frequency only gradually. Assuming that the sound of the siren was composed of partials that were in accordance with Fourier's theorem, researchers such as Helmholtz or Jenkin and Ewing could infer that the transposition of spectra was feasible. In the howl of the siren, one could not make out any apparent change in color.

With its feature of transposing entire sound spectra, the phonograph opened up a new possibility of testing the two explanations for sound color Helmholtz had offered. His explanation for the tone color of musical instruments implied that their sound should not be affected by transposition, while his explanation for the tone color of vowels implied that transposition would cause distortions. The phonograph thus suggested the *experimentum crucis* to decide between these two explanations. Jenkin and Ewing heard no change in tone color. Again, the immediate response, this time by Charles Cross, showed that this experiment involved more than just the observation of physical phenomena. The vowels form a system of differentiations that allows for great deviations, while maintaining the ability to communicate the differences.

As it turned out, the first experimenters had to sort out what the term *quality* actually referred to when applied to the distorted vowels. Soon after they had published the first notice in a letter to the editor of *Nature* Jenkin and Ewing wrote the following:

> We venture, however, to remind any one trying the experiment that a low note followed by a high one suggests a change from *u* (Italian) to *i*. Thus if we whistle a low note and then the octave to it or a note near this, the ear is easily persuaded that the whistle resembles *u i*, but if now, beginning again on the note we just thought was *i*, we go up another octave, the new sequence again suggests *u i*, although the very note which was last taken to represent *i* now stands for *u*. If, therefore, we wish to judge what a sound really is we should not trust much to contrast, especially when a change of pitch is involved in the comparison. (Jenkin and Ewing 1878b, 167)

Howls

In 1914 and 1916, when Stumpf carried out his vowel experiments, his situation was very different. For one thing, he noted the awkwardness of his situation: In the laboratory, he and his assistants listened to almost imperceptible sounds while outside, beyond the city limits, the war roared. This silence is documented on one of the cylinders, which contains a soft noise, showing the attempt to use the phonograph for the investigation of whispered vowels. The analysis of the whispering voice had by then become a standard item in the investigation of the resonances of the mouth cavity. Dutch physiologist Franciscus Cornelis Donders had inferred from Helmholtz's investigation that the mouth cavity would render its tone even without being stimulated by the vocal cords. This gave rise to the question of intelligibility, which was to be investigated in terms of communication technology (Schmidgen 2007).

In a very different sense, however, Stumpf and his team listened to the howl of the siren. All of a sudden it appeared as a constant change in sound quality. A new way of listening posed the question of the vowel sound anew, but the object of listening was now the apparatus and its properties. The phonograph turned from a technical device into an object of investigation. The Berlin laboratory for experimental psychology, after more than ten years of work building the phonogram archive, was well equipped with a number of different phonographs. The laboratory protocols reveal that some experiments were carried out with a device called a "parlograph," designed for office use where it was supposed to substitute for face-to-face dictating.[3] The parlograph thus exemplifies a specialization in the development of the phonograph by focusing on one of the functions its inventors had been busy promoting.[4] Stumpf's interest was more in comparing the recording devices that were available with regard to their potential use in musicology and experimentation. The instrument used in most of the experiments, however, was a phonograph that was more appropriate for the purpose of changing the rotation speed. Its range of possible rotation speeds was large, allowing for a triple augmentation of the lowest speed. Together with his assistants, Stumpf carried out two series of tests—eight wax cylinder rolls in all were recorded.[5] The first series consisted of three cylinders, one for each rotation speed: slow, normal, and fast. These cylinders clearly revealed the experimental nature of the enterprise. On one cylinder, a voice is clearly heard asking for the tuning forks as the next item to be recorded: "und jetzt die Gabeln" ("and now the forks"); a howling sound follows this speech. It appears that the fork had been brought too close to the recording funnel and had thereby distorted the sound.

A list of the recorded sounds is given in the protocols, as well as in Stumpf's report in *Die Sprachlaute*. In addition to sung vowels, the cylinders recorded the sounds of tuning forks, organ pipes, and artificial vowels produced with a vowel tube (a device developed by Robert Willis in the 1830s). Thus, the recorded items combined sounds of the voice with sounds of laboratory instruments. All of these sounds were carefully chosen to enable maximal control of distortion. For instance, on the first series of cylinders not all vowels were recorded, only the *u* and *o* were juxtaposed. With only two vowels the systemic effect of recognizing the whole sequence of vowels could be avoided—a problem that had led former researchers to overhear the actual distortion of the sounds. The choice of these two vowels was sufficient to verify Helmholtz's assumption. Stumpf agreed with Helmholtz in that he took *u* to come closest to a sound with only one component of no fixed pitch. Thus, *u* should remain unchanged when the rate of rotation was altered. An alteration of *u* should in turn indicate that something was wrong in the experiment. In contrast, *o* should easily turn into an *a* when the speed was increased if Helmholtz's hypothesis about absolute pitch characterizing vowels was correct. The change in speed should not only alter the vowels but also create a difference between them on account of their transposition.

The next series of five cylinders focused on sung vowels, juxtaposing them with two spoken words and a series of tuning fork sounds. For these cylinders, the complete series of German vowels, including *ü*, *ö*, and *ä*, was recorded, followed by the words *Kuckuck* (cuckoo) and *Uhu* (owl). Five recording speeds were tested by replaying the recording at the same speed, as well as a number of different speeds. The distortions varied and pointed to different problems in recording. The tuning forks indicated the frequency range in which a recording could be made. Under certain conditions, their sounds would simply disappear. For the other sounds, squeaking and bleating tones were heard, as were resemblances to various musical instruments. In most cases, these changes could be explained by the so-called formant theory, which assumes stable amplitude peaks in the frequency spectrum. When using very low or very high rotation rates, the distortions were less easy to understand. Additional overtones appeared: *Kuckuck* turned into the nonsense syllables *Tretre.* Stumpf concluded that such phenomena must be explained by physical distortions that occurred when the phonograph was used in extreme ways. In other words, as any other medium, the phonograph had a linear characteristic for only a small region. Beyond the limits of this region, nonlinear distortions occurred. Using vowel sounds as objects for their experiments in recording quality, Stumpf and his team found two characteristics of recorded sound that were of the utmost significance for the use of the phonograph in ethnomusicology. The first was that sound color changed when the reproduction speed was altered. As long as the musicological investigation of the recorded sounds had not yet determined which of its characteristics were significant, such distortion could endanger the significance of the whole enterprise. Second, with the use of sung vowels and spoken words as the object under investigation, they also showed that an incorrect reproduction speed could destroy the meaning of a recorded item.

Cylinders

The group of researchers who took part in these experiments was remarkable in itself. Stumpf was assisted by, among others, Max Wertheimer and Erich Moritz von Hornbostel (i.e., by one of the founders of Gestalt psychology and one of the founders of ethnomusicology).[6] The latter had been director of the Phonogram Archive for more than a decade. Although this was still not an official position, Hornbostel had invested a considerable amount of time and money in the enterprise. In his growing compendium of published work, methodology was a central issue. Most notably, two articles he coauthored with Otto Abraham laid the foundation for comparative musicology, both giving center stage to the phonograph: *Über die Bedeutung des Phonographen für die vergleichende Musikwissenschaft* (On the Meaning of the Phonograph for Comparative Musicology) (1904) and *Vorschläge für die Transkription exotischer Melodien* (Suggestions for the Transcription of Exotic Melodies) (1909), where transcription meant mostly transcription from recordings. Most of Hornbostel's subsequent publications on specific musical examples were based on the collection of the archive, often pointing to this origin with titles such as *Phonographierte türkische Melodien* (Phonographed Turkish Melodies) and *Phonographierte Indianermelodien aus British Columbia* (Phonographed American Indian Melodies from British Columbia).

In cooperation with Felix Luschan, the first chair of ethnology at Friedrich-Wilhelms University in Berlin, Hornbostel prepared instructions for travelers on how to use the phonograph in the field. It was integrated into a guide for ethnological travels published in the journal *Zeitschrift für Ethnologie* (Journal for Ethnology). The Phonogram Archive handed out an offprint of this guide to travelers who were willing to make recordings and bring them back to Berlin. In many cases, the phonographs themselves were also provided by the archive, as were tuned whistles to be used to indicate the rotation speed. In the article, significant consideration was given to how the recordings in the archive might be used. In order to safely identify them, some preventive measures had to be taken. As any written information about a roll could get lost or be attached to the wrong item, the travelers were instructed to record the identifying data directly onto the wax cylinder. They were instructed to first blow the whistle and then briefly classify the provenance of the recording. The rotation speed could later be easily identified from the pitch of the whistle. This instruction added an acoustic tag to the recording, which became the basis for comparison. Without this tag, the recording of unknown sounds would be useless for the musicologists using the archive. With the help of the whistle, however, the traveler could safely identify the speed of the recording and thus guarantee that the sound color was correctly reproduced. As a consequence, the traveler could deliberately choose whether greater length or higher quality were more important in a given situation. The texts of epic poetry, for instance, would often require more time, while for music better quality seemed indispensable. This choice was backed up by the pitch tag, which connected the recording to the collection of other items in the archive.

In 1908 the *Phonographic Journal* reported on a recording that had been made in the name of preserving the culture of a Slavic people living in the Lausitz region of Germany. The trip that led to the recording was organized in March 1907 by the author of the report, Baron von Hagen. Hagen had invited the members of the Phonogram Archive to join him in recording "Wendish" music. This was the German name for the Slavic minorities living in German territory.

> On behalf of Geheimrat Stumpf (the Psychological Institute had been invited), Dr. Hornbostel appeared with a small phonograph. However, Dr. von Hornbostel recorded only the spinning songs of an old Wendish woman because Geheimrat Stumpf has not yet shown interest in [recording] speech or in things already set to music (von Hagen 1909, 460).

Baron von Hagen had other interests, as he declared in this and other articles that he and like-minded people published in the journal. He believed it should be the responsibility of a phonogram archive to preserve and foster German culture. This required archiving the voices of prominent people and making a survey of the German dialects and the non-German languages spoken within the territory of Germany. For teaching purposes, a third section of the archive should contain samples of languages other than German. A fourth section should provide materials for physiology and voice therapy. The last section, he suggested, should be a music collection, divided in two parts, one part containing vocal samples for the teaching of singers and the other—corresponding to what the Berlin Phonogram Archive already did—with samples of music from all over the world (von Hagen 1909, 382). In the late nineteenth and early twentieth century, the obsession to inscribe one's own culture into history also turned into an obsession with preserving one's present. The phonograph offered a twist on this desire for preservation, a twist that projected it into the future because the phonograph created as it preserved (Sterne 2003, 332–3; Hoffmann 2004). All over Europe similar activities took place, such as the Musée phonographique in Paris (Brain 1998, 277ff.) or the later activities of German linguist Wilhelm Doegen for the German Sound Archive (Lange 2007).

Von Hagen's somewhat eclectic program was held together by commercial interests. Hagen urgently advised the Phonogram Archive to get in touch with the emerging recording industry, which, he hoped, would support them in collecting samples of languages and music abroad. This link between the professional recording industry and scientific enterprises has been noted elsewhere in this handbook (e.g., Bruyninckx, Whittington, this volume). Most important, Hagen tried to convince the Phonogram Archive to abandon the phonograph and to use gramophone technology. The main advantage of the gramophone was that its discs were easier to copy. Copying initiated the double success of the gramophone on the market, and soon it surpassed the phonograph. In contrast to the phonograph and its cylinders, the gramophone and its records thus split into two industrial branches. Selling sounds on gramophone discs became a business in its own right, and the sound quality became subject to competition and secrecy. Duplication technology, of course, was the technological basis for the commercial success of the discs. Phonographic recordings posed greater difficulties in copying. Hornbostel, a trained chemist, eventually succeeded in solving this problem. Electroplating allowed a matrix to be made of the cylindrical shape of phonograph recordings. For a while, the Berlin Phonogram Archive even led the technology of duplicating wax cylinders. Although this method was risky (it destroyed the original in the process of the galvanoplastic duplication), other collectors trusted Hornbostel's method to such an extent that they sent their originals to Berlin in order to obtain "galvanos" (i.e., the matrices) and copies in exchange. This allowed the collection in Berlin to grow even faster as a copy of each electroplated cylinder was kept. For commercial purposes, however, the method was too costly. The material used to make the copies was found only after a long series of trials.[7] The phonogram archive repeatedly appealed for funds, mostly asking the government to support the work.[8]

Baron von Hagen and an anonymous supporter ridiculed the phonogram approach in numerous articles published in the *Phonographische Zeitschrift*.[9] They pleaded for a strong commitment to the gramophone's recording and duplicating methods as this would open up the potential for a self-sustaining basis for the archival work. Gramophone discs could be sold to schools or to individuals interested in learning foreign languages and thus would return some income to the scientific enterprise.

Abraham and Hornbostel, however, opted for the technology that enabled users to record themselves. What was even more important to them was the possibility of manipulating recordings for research purposes. They discussed the pros and cons of the "phonographic technology" at hand in their 1904 article on the significance of the phonograph for comparative musicology:

> In recent times, phonographic technology has made great progress. The phonograph was followed by the gramophone, and both apparatuses contest each other, each has its advantages and shortcomings. Both use membrane vibrations, which are transmitted to a pivot by a lever, which in turn writes its movements into the waxen surface. The phonograph does this vertically, punctuating its movements into the laterally moving wax cylinder. In contrast, the gramophone uses discs instead of cylinders; the pivot draws the undulating shape of the tonal vibrations onto the discs' surface. (Abraham and Hornbostel 1904, 231)

The exact knowledge about the gramophone's recording technology, Hornbostel and Abraham added, remained an industrial secret. For this reason the gramophone could not be used for private recordings.[10] A great advantage of the gramophone was the convenient storing of discs. To this end, the Viennese Phonogram Archive, which was established shortly before the Berlin Archive, had invented its own method of transcribing wax cylinders onto discs, using vertical cutting similar to Edison's phonograph. This technology, however, tied the apparatus to its location. It was so heavy that it had to remain in the rooms of the Austrian Academy of Sciences, which hosted the archive. The phonograph, in contrast, was easy for one person to carry. In his travels to the Lausitz, Hornbostel brought only a small phonograph. However, the recordings he made were futile, not so much because of their allegedly inferior quality but because he was not allowed to play them. These recordings are preserved today in the archive, but in every container there is a note stating "playing forbidden." The right to market and to listen to them belonged to von Hagen only.[11]

In the Berlin archive, the phonograph remained in place as *the* recording device. Although, back in 1900, Stumpf had been given an opportunity to try wire recording—then called "telephonography"—the archive stayed with the wax cylinders. Over the years, methods of identifying the cylinders were developed, the safest being inscription on round labels that were glued to the cylinders' boxes. These labels were printed for the Psychological Institute, allowing for the inscription of categories such as inventory and catalogue number, as well as the tribe, object, person reciting and person recording, and the place and date of the recording. Most often, these inscriptions were repeated on the bottom of the box to minimize the danger of errors. These boxes were also used for the copies that the archive obtained from collectors who had asked for galvanos.

For the experimental recordings, these identifying measures were only rarely used. A collection of song performances initiated by Otto Abraham as early as 1907 to measure how closely performances matched given intervals is still stored in boxes with archive numbers 1401 to 1416 and catalogue numbers Exp. 18 to 34. But the identification of many others still remains questionable. The recordings were not copied, so the boxes contain the original wax cylinders. In addition to damage from mold, the recordings are spoiled in many places by the distortions produced by repeated playback of specific parts, thus clearly pointing to the methods that were used when measuring the recorded songs. When listening to the recordings, the musicologists used the cylindrical shape to create loops. As Hornbostel and Abraham wrote in their methodological instruction, "In order to get to hear a single note in isolation, one has to make the membrane [i.e., the needle] touch the cylinder while hindering its lateral movement by switching off the guide conduct. This method, however, deteriorates the recording" (Abraham and Hornbostel 1909/1910, 17).

Abraham's recordings make this deterioration palpable. Abraham published his results in 1921 in an article titled "Tonometrische Untersuchungen an einem deutschen Volkslied" (Tonometric Study of a German Folksong) (Abraham 1923). In order to get people to sing in an automated manner rather than reflect on the pitches, Abraham chose to have the national anthem serve as the "folksong" in question. Hornbostel, who had perfect pitch, recorded the anthem several times. He whistled it and sung it without words, first in one key, then transposed by one half-tone, and then very low and very high. His performance as it is preserved today is interrupted many times by the traces of measuring isolated notes. The recording eventually gets stuck when Hornbostel sings in the highest register—the cylinder loops his crackling voice when he bursts into laughter at his own singing.

Conclusion

The historiography of recording has done great service in enumerating technical devices: First, the phonograph was invented, shortly after that the gramophone, then around the turn of the century, wire recording comes in, and so forth. Not surprisingly, the straightforward accounts, indispensable and rich in historical and archival detail as they may be, have long been challenged. It has remained difficult, however, to focus on technology at the same time as integrating it with cultural history.

An important achievement in this respect has been Friedrich Kittler's quest for the technical conditions of cultural strata, which brought about a new perspective on technology. Given that at the time of Kittler's first pathbreaking writings (1990, 1999), the computer was opening up a new reality of media use, this search for the technical *a priori* was also pertinent to a new theory of media—one that could describe how symbolic codes were dissolved by self-registering apparatuses only to be turned into symbolic code again, if on a completely different, binary level. Sound, for example, was transformed into curves to be then digitally encoded. For the problem ethnologists encountered when they transcribed the music engraved on wax cylinders, computer technology developed new solutions. A century after Hornbostel and Abraham wrote down their ideas, musicians and ethnologists are now able to use special functionalities for transposition in sound software. These tools use digital encoding to avoid the distortion of pitch and sound quality that occurs when a recording is replayed at a slower speed in the analogous mode.

Media analysis in the wake of Kittler's search for technological *a priori* thus set for itself two stable entities: a contemporary point of departure, such as the computer and the discursive network enabled by the computer on the one hand, and a history of symbolic encoding, binary calculus, the history of investigating temporal resolution on the other hand among the conditions that made computer technology and its uses possible. Moving backward from a given state, the analysis of the technical *a priori* eventually discovered some primary conditions for this state. Around the turn of the twenty-first century, media studies started to question the historical framework of this analysis. Since then, media analysis has been understood to help focus on the instability of the notion of a medium. Focusing, for example, on a historiography of media, such studies show that most accounts of media technology could not work without a notion of medium that took its definition for granted rather than explaining it. While this had been excusable with regard to the simple account of technological development, in later histories of recording technology, such a stable notion of medium was concealed as well. The history of recording and its meaning for an auditory culture often presupposed that, once the phonograph was invented, any of its later uses could have been anticipated.

When viewing technology as the condition of culture one can easily get trapped in this presupposition. Other accounts of recording history have therefore strived to keep the definition of a device open to redefinition. For instance, Emily Thompson has urged researchers in her account of the history of the phonograph to accept that just after its invention "there was no single role or purpose for the invention to fulfill. The phonograph appeared before a need for its function had been identified" (Thompson 1995, 137). With this methodological caveat in mind she did indeed keep her approach to the history of the phonograph open, particularly with respect to an important element in the historiography of media—feedback, in her case feedback between consumers and technology. Obviously, however, the functions of the phonograph were not exclusively defined by consumers. One should not underestimate the importance of finding the modernity of the phonograph in consumption any more than one should also stress that consumption is always bound to some consumable object.

What is important in this story of the phonograph also within the context of science and technology studies is that it is not simply a story of black boxing. When dealing with the phonograph as the object of study, one must keep in mind that a process of standardization covers only some of the important aspects of the phonograph as a medium. A narrative of standardization has an inherent directionality: It tells how a function becomes fixed or, in other words, black boxed. While both the functions of recording and playback and the concrete instrument of the phonograph became standardized to some extent during the time the phonograph existed, their interplay often counteracted standardization. The black box had to be reopened, and some light had to be shed on its functioning, thus turning it into a gray box.

The story of the vowel experiments proposes a different approach to the history of the phonograph because it foregrounds the interaction between scientists and technological development.[12] This story traces the multiple shifts from exploring sounds by using a specific instrument to exploring a technology by using specific sounds. Introducing the phonograph as a scientific instrument allows the shift from an object to a means of investigation to be described and vice versa. As shown, the phonograph was immediately accepted by acousticians as another recording device. Technology thus takes center stage, but it also puts the emphasis on manipulation rather than standardization. Aside from the history of technical development and the history of its uses, there is a history of the phonograph as an unstable object—a gray box—in the context of research.

The story of the vowel experiments mirrors the various histories of the phonograph in a peculiar way. While every experimenter who repeated this experiment usually pointed to the improving quality of the device, the word *quality* describes this change insufficiently. A detail in the functioning, such as the rotation speed, must be understood differently in different historical contexts. Varying the speed meant different things in each case. If for Fleming and Jenkin speed was just one technical element among many that they had to control, rotation speed turned out to be the crucial characteristic of this new device because it allowed for the manipulation of recorded sound. After 1900, the situation changed profoundly. Ethnology brought new uses for the phonograph. Ethnological recordings, however, were worthless without information about the rotating speed. Still, ethnologists, did not want see the speed of recording and replaying be shut away in a black box. They preferred to stay in charge of this technical detail. Asking travelers to measure the speed by recording a known note, the ethnologists similarly avoided losing control of the issue of standardization. With such details, the phonograph points to features of sound recording that would become central in further research on sound and hearing: recurrence and manipulation. As a technological object, the phonograph quickly stabilized. Its basic elements—the needle, the barrel and spring, the membrane and funnel—point to functions such as engraving, transport, and amplification. Because they can be found at any stage of the technical development of sound recording, they are not specific to the phonograph but rather pertain to sound recording in general. Also, particular uses of the device soon crystallized, which proved to be of considerable social impact.[13] On closer inspection, however, none of these functions and uses were as stable as they seemed. Rather, in order to understand what could be done with a phonograph, one had to consider what could *not* be done with it. The specificity of the phonograph did not reside in its stable functions and uses but rather in a specific instability. A historiography of media has to look at the "becoming-media" (Vogl 2007), that is, the gradual coming into being of media, as Joseph Vogl has suggested.[14]

Media involve perception. However, at the same time they replace it with technology. First, the phonograph created sounds that turned perception upon itself: In the context of experimental psychology, the phonograph enabled the experimenter to retain the identity of the investigated recording, while at the same time producing variation in the perceived phenomena. Second, the phonograph thereby created points of reference: In the context of the phonogram archive, recurrence was essential, guaranteeing the repeated accessibility and the identity of the recorded phenomenon in each act of investigation. Finally, the phonographic recording provided a field of possible perception—the archival collection of data that would be open for questions that the researchers could not yet foresee. This collection brought into awareness that it would remain incomplete not so much because there was always more to be collected but more so because there would always be new ways of dealing with the preserved material. For comparative musicology, which would later be renamed ethnomusicology,[15] the phonograph provided the elementary technology for recursion and comparison. Its use in these emerging disciplines was supported, however, by a separate strand of research that intersected with ethnomusicology in the Berlin laboratory. Here, functions of the phonograph were tested (Bijsterveld, this volume), simultaneously revealing functions of hearing. These experiments involved more than science. Consumer uses, political interests, and cultural settings shaped the ways in which the experiments employed the phonograph, as well as the ways in which their results were fed back into culture. These experiments took place at the intersection of music psychology, ethnomusicology, experimental phonetics, and psychology—the phonograph serving as the point at which these disciplines converged.

NOTES

1 Ziegler (2006, 83) mentions 106 cylinders in the collection of "Experimentalaufnahmen" (experimental recordings). A number of digitized recordings from this collection are available at http://vlp.mpiwg-berlin.mpg.de/library/audio.html (accessed 30.09.2009).

2 Accounts of the history of speaking machines are given in Ungeheuer (1962, 1983); Hankins and Silverman (1995, 179–220); and Felderer (2002). Further attempts to construct speaking devices are mentioned by Hankins and Silverman (e.g., by Pope Sylvester III, Robert Hooke, and, in the late eighteenth century, the Abbé Mical and Erasmus Darwin).

3 Cf. Ethnologisches Museum Berlin, Preußischer Kulturbesitz. Berliner Phonogramm-Archiv: Carl Stumpf Papers on Acoustics, Envelope 17, Phonographische Versuche.

4 For the use of the phonograph, see Thompson (1995); more generally on early recording, see Reed and Welch (1994).

5 Cf. http://vlp.mpiwg-berlin.mpg.de/library/data/lit38711, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38712, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38713, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38894, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38895, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38896, http://vlp.mpiwg-berlin.mpg.de/library/data/lit38897, and http://vlp.mpiwg-berlin.mpg.de/library/data/lit38898 (accessed Sept. 30, 2009;, cf. footnote 2).

6 On Wertheimer as a pupil of Stumpf see Ash (1995); on Hornbostel see Klotz (1998).

7 The recipe for this was lost until 1989, when the Berlin collection was reassembled. See Ziegler (2006).

8 Cf. the appendix in Kaiser-El-Safti (2003).

9 Anonymous (1907, 1908); von Hagen (1908); cf. also Stumpf (1908).

10 Like the phonograph, the gramophone was originally a recording *and* a replaying apparatus. Cf. Moore (1999).

11 Cf. Susanne Ziegler's comment in the booklet to *Music! 100 Recordings: 100 Years of the Berlin Phonogramm-Archiv 1900–2000* (Wergo LC 06356 2000), 125–27.

12 In this respect, my account of the phonograph comes close to the accounts of interaction between instruments and their users given in Joerges and Shinn (2001).

13 The use of the phonograph has been critically reviewed by Jonathan Sterne (2003) under the heading of "A Resonant Tomb." Here, Sterne shows how preserving sound for eternity became a leitmotiv in the discourse on the phonograph.

14 Vogl (2001, 2008) and more generally the corresponding issue of the *Archiv für Mediengeschichte* with a focus on media historiography, ed. Lorenz Jäger, Bernhard Siegert, and Joseph Vogl, as well as the issue on "New German Media Studies" in *Grey Room* (29) (Winter 2008), ed. Eva Horn.

15 The discussion about the naming continued until the 1950s; cf., for example, Kolinski (1957).

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