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Fine-Tuning Philology: Helmholtz's Investigation into Ancient Greek and Persian Scales

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ABSTRACT

This article discusses how Hermann von Helmholtz's inquiry into Ancient Greek and Persian musical scales contributed to musicological methodology and the formation of new musicological subfields and how his auditory physiology spurred an interest into the harmonium as an instrument for exploring tuning systems. In so doing he shifted the description of intervals from "just" to "pure." Calling an interval "just" was a judgment that was based on testing whether its sound corresponded to its antecedent mathematical definition. The criteria for calling it "pure," in contrast, depended in the first instance on hearing. This shift corresponds to a tendency in nineteenth-century experimental life sciences to replace hypothesis-driven with exploratory experimentation. Helmholtz projected this back to the Persian use of lutes, which he claimed to allow for such exploration. Although failing to acknowledge the filiation of textual sources, he thereby introduced a new approach to the study of remote musical cultures.

In May 1862, Hermann von Helmholtz gave a lecture titled "On the Arabo-Persian Scale."[1] The speculations about genealogical relationships among Persian, Arabic, and Ancient Greek scales he presented there could be seen as preparing the ground for the emergence of the discipline of comparative musicology in the first decades of

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1. [Hermann von] Helmholtz, "Ueber die arabisch-persische Tonleiter," *Verhandlungen des naturhistorisch-medizinischen Vereins zu Heidelberg* 2 (1862): 216–17.

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the twentieth century. Comparative musicology not only shared the interest in genealogical hypothesizing, it also can be said to belong to a research paradigm that is often referred to as "armchair" anthropology and ethnology.[2] However, the context for speculating about music's remote past needs to be looked for in the experimental life sciences. The beginnings of the Berlin group of comparative musicologists, for instance, lie in the Berlin University's Institute of Psychology. Helmholtz, in turn, wrote his major contribution to the research on hearing and music, the book *On the Sensations of Tone as a Physiological Basis for the Theory of Hearing* (first published in 1863), while working as professor of physiology at the universities of Bonn and Heidelberg.[3] Educated as a military surgeon, Helmholtz became one of the major figures of experimental physiology in the 1850s, before being appointed as chair of physics at Berlin University in 1872.

As a writer on ancient music Helmholtz relied on the work of philologists and on the sources for ancient music theory that they had made accessible during the first half of the nineteenth century. So, at first sight, his writings seem to be a discussion of other people's scrutiny of texts. Yet, he read the sources as testimonies for modes of listening that had emerged under different material conditions than those of his own times, and he then took his readings back to his "laboratory." In this article, I aim to show how Helmholtz's speculations interlock with his experimental investigation into the material conditions of hearing. As I argue, his comparison of Greek and Persian scales confronted two modes of listening that could be compared to two modes of experimenting, namely, theory testing and exploration. In so doing, he developed what I will call an "exploratory mode of listening." The centerpiece of the laboratory setting he created for this was a harmonium in just intonation. This instrument served as a means to highlight the physiological effects of sound and to sharpen the contrast with the sorts of instrument used in everyday musical life; in short, it presented the sound under investigation as genuinely unfamiliar. Together with the harmonium as an instrument

2. On the history of comparative musicology, see Lars-Christian Koch, "Images of Sound: Erich M. von Hornbostel and the Berlin Phonogram Archive," in *The Cambridge History of World Music*, ed. Philip V. Bohlman (Cambridge: Cambridge University Press, 2013), 475–97; Dieter Christensen, "Erich M. von Hornbostel, Carl Stumpf, and the Institutionalization of Comparative Musicology," in *Comparative Musicology and Anthropology of Music: Essays on the History of Ethnomusicology*, ed. Bruno Nettl and Philip V. Bohlmann (Chicago: University of Chicago Press, 1991), 201–9; Sebastian Klotz, ed., *Vom tönenden Wirbel menschlichen Tuns: Erich M. von Hornbostel als Gestaltpsychologe, Archivar und Musikwissenschaftler* (Berlin: Schibri, 1998).

3. On Helmholtz and music more generally, see Benjamin Steege, *Helmholtz and the Modern Listener* (Cambridge: Cambridge University Press, 2012); Erwin Hiebert, *The Helmholtz Legacy in Physiological Acoustics.* (Cham: Springer, 2014); Julia Kursell, *Epistemologie des Hörens: Helmholtz' physiologische Grundlegung der Musiktheorie* (Munich: Fink, forthcoming).

for listening to music afresh—and this is the hypothesis of this article—the exploratory mode of listening can be seen to gesture toward the beginnings of comparative musicology and link up with attempts to relate to Western tonal music in new ways.

This article has three parts. In the first part, I will introduce Helmholtz's 1862 lecture on the Arabic and Persian scale and relate it to an earlier lecture he gave on his harmonium and its specific tuning. The second part will turn to the harmonium as a site of experimentation in Helmholtz's physiological work more generally. In the third part, I will reflect on exploratory experimentation as a search for what is as yet inconceivable. The conclusion looks ahead to early comparative musicology.

A PHYSIOLOGIST'S USE OF PHILOLOGY

During the years before Helmholtz finalized the manuscript of his book *On the Sensations of Tone*, he tested parts of his argument in various small papers. Some of these papers, though published in scientific journals and proceedings, dealt, strictly speaking, with music. Among these were a lecture titled "Ueber musikalische Temperatur" (On musical temperament), given in November 1860, and one titled "Ueber die arabisch-persische Tonleiter" (On the Arabo-Persian scale), given in May 1862. The argument of the latter went as follows. When tuning a sequence of eight fifths one could produce an interval that came close to the proportion of 5 : 4 or, in other words, a third in just intonation. Persian and Arabic musicians were, in Helmholtz's view, not only likely to have made use of such a tuning, but they must also have discovered the properties of this interval. In the earliest Greek sources Helmholtz knew of, the just third was not mentioned. The concatenation of four fifths, known as Pythagorean tuning, in contrast produced a third that differed considerably from this proportion. The just third appeared only later, in texts by Alexandrian authors. The just third, and just intonation more generally, Helmholtz concluded, was thus likely to be an Arabic or Persian discovery, rather than stemming from Ancient Greek music.

It may seem surprising that the audience of this and the earlier lecture, the Heidelberg Association of Natural Historians and Physicians, would have been able to follow such a detailed discussion of musical matters. As historian of science Alexandra Hui has pointed out, at a time when one typically had to make music oneself if one wanted to listen to music, knowledge of music was more widespread than we tend to think today.[4] Tuning, in addition, was a prominent topic in physics journals from the first half of the nineteenth century, due to its relevance for controlling sound in acoustic

4. Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840–1910* (Cambridge, MA: MIT Press, 2013).

experimentation.[5] Yet, Helmholtz's peculiar interest in the question of tuning reached out toward sensory physiology. For his research on hearing, this was an obvious subject matter, as the effects of just intonation can be striking. Its use of simple ratios among the basic frequencies of two notes minimizes certain distortions that occur in the superimposition of sound waves considerably, and it was this contrast between distorted and pure sound that attracted Helmholtz's interest.[6] When it came to the sense of hearing, a "Physiologie im eigentlichen Sinne"[7]—or physiology in the true sense of the notion—could be built on an investigation of how music dealt with these phenomena. After all, the music of Helmholtz's own time favored steady sound with constant pitch, in which the phenomena in question were particularly prominent. Music history, in turn, could offer insights into how musicians reacted to the effects of distortion in periodic sound under different conditions.

In his own experimental research Helmholtz opted for using an instrument in just intonation, so as to detect the effects of undistorted purity and compare it to distortion. The harmonium was particularly well suited for this, as it produced tones with a stable pitch that continued as long as a stream of air was provided. Helmholtz ordered a harmonium for laboratory purposes from the Stuttgart-based company Schiedmayer. The tuning system he asked the company to use was that which he later described to his Heidelberg audience. To be sure, Helmholtz's concept of just intonation included some approximations, which he deemed tailored to suit the purpose of the instrument. Yet, this concept of approximation was a scientist's, not the kind of congruence that music theorists tacitly implied between ideal types and their accidental realization in actual sound. Many music theorists of his time tested their findings on the piano. The piano, however, combined the rich spectrum of struck strings with equal temperament, that is, a tuning system that projects all tonal relations onto an equidistant grid. This tended to encourage musicians to find in the sounds they heard what theory had led them to expect, and to discourage them from listening to the actual sounds.[8]

5. On this, see Myles Jackson, *Harmonious Triads: Physicists, Musicians, and Instrument Makers in Nineteenth-Century Germany* (Cambridge, MA: MIT Press, 2006).

6. See H[ermann von] Helmholtz, *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (Braunschweig: Vieweg, 1863), ix. Alexander Ellis translates this as "On the Interruptions of Harmony," anticipating that and how Helmholtz predominantly discusses beats in this chapter. See Hermann L. F. Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, translated by Alexander J. Ellis (London: Longmans, Green, 1875), xix.

7. See Helmholtz, *Tonempfindungen*, 6, and *Handbuch der Physiologischen Optik* (Leipzig: Voss, 1867), 427.

8. See Julia Kursell, "Musiktheorie Hören: Hermann von Helmholtz und die griechische Antike," *MusikTheorie: Zeitschrift für Musikwissenschaft* 22 (2007): 337–48, and "Noten lesen," in *Medien-*

Diese Leiter ist nach einer Reihe von 17 Quinten gestimmt, nämlich:

c — g — d — a — e — h — fis

das fis können wir auch Ges schreiben und dann fortfahren: Ges — Des — As — Es — B — F — C — G — D — A — E.

Figure 1. Sequence of fifths, in Helmholtz, "Ueber die arabisch-persische Tonleiter," 216.

When Helmholtz encountered translated fragments from fourteenth-century Persian music theory in Raphael Georg Kiesewetter's 1842 study *The Music of the Arabs*,[9] he was surprised to recognize his tuning system in the descriptions of the Persian scales. But whereas Kiesewetter emphasized that the Arabic and Persian scales comprised microtonal intervals—that is, intervals that were smaller than those used in the European musical tradition—and should therefore be considered as independent from contemporary music theory in Middle Ages Europe, Helmholtz first of all felt reminded of his own search for obtaining a meaningful tuning system. The fact that the piling of pure fifths resulted in two alternative pitches for certain steps in the Western scale, such as the third, made him speculate that tuning in fifths was the basis also for the microtonal scales described in Kiesewetter's sources.

The paper on Arabic and Persian scales provided two representations of the pitches involved. Using lower and upper case letters, Helmholtz first presented a sequence of fifths—note that he considers "fis" (F-sharp) in the upper row equivalent to the note "Ges" (G-flat) in the lower row.[10] The resulting sequence showed where the concatenation reached different pitches with the same name in the European system (fig. 1). Helmholtz then rearranged these notes according to their names (fig. 2). Arranged in a single lineup, the tuning in fifths resulted in a series that displayed two notes rather

philologie: Konturen eines Paradigmas, ed. Friedrich Balke and Ruppert Gaderer (Göttingen: Wallstein, 2017), 172–95.

9. R[aphael] G[eorg] Kiesewetter, *Die Musik der Araber, nach Originalquellen dargestellt* (Leipzig: Breitkopf & Härtel, 1842).

10. The switch from the lowercase "fis" to the upper case "Ges" hides a difference that recurs in the other steps. The almost just third that Helmholtz himself mentions occurs between the lower case e (that should be written as the less common note name "Fes") and the upper case C. Written in such a way it would not look like a third to the nineteenth-century reader, however, who would describe it as a twice diminished fourth, and thus an interval that does not have a proper place in the European pitch space. The lowercase letter, however, is also used by Helmholtz for the just third proper, that is, the interval that results from the proportion of 5 : 4 rather than a concatenation of fifths.

C — Des — d — D — Es — e — E — F — Ges — g — G — As — a —
B — h — c — C.

Figure 2. The basic pitches of Helmholtz's Persian scale

than one for certain European steps in the scale. What these additional steps introduced instead was a number of—almost—pure intervals. A number of selections from the whole range of steps could, in a further step, reproduce the modes or scales that were known to be part of the Persian and Arabic tonal system. Each of them distributed "pure" intervals in a different way, some favoring pure fifths, others pure thirds. Helmholtz categorized three of these modes as "Greek," as they were built from pure fifths only, and five as "natural," as they displayed the almost pure thirds he had detected in his own tuning system (fig. 3).

From here, Helmholtz proceeded to speculate about how the experience that Persian musicians had with lutes could have been transmitted to certain sources in Greek antiquity. More concretely, he claimed that the late occurrence of pure thirds in Alexandrian authors such as Didymus and Ptolemy might point to a potential genealogy of this interval as stemming from Persian music. This hypothesis presented a remarkable difference with regard to Kiesewetter's argument. Kiesewetter tried to disconnect to the greatest possible extent the music of the "Saracens" from the Western tonal system. He included extended translations from the original sources with the aim of contrasting them with medieval European music theory. Finding intervals in the Persian scales that were smaller that those used in European music, he took this as proof that Persian music did not share the interest in ratios of small integers that was the backbone of European music theory.

Helmholtz ignored Kiesewetter's speculations on potential relations between Latin and Arabic sources from the Middle Ages, and he deliberately disregarded the histor-

A. Griechisch
Tonart Uschah: C — D — E — F — G — A — B — C.
Tonart Newa: C — D — Es — F — G — As — B — C.
Tonart Buselik: C — Des — Es — F — Ges — As — B — C.
B. Natürlich
Tonart Rast: C — d — e — F — G — a — B — C.
Tonart Sengule: C — D — e — F — g — a — B — C.
Tonart Rehawi: C — d — e — F — g — As — B — C.
Tonart Hussein: C — d — Es — F — g — As — B — C.
Tonart Hidschef: C — d — Es — F — g — a — B — C.

Figure 3. "Greek" and "natural" modes in Persian music theory as derived from Helmholtz's Persian scale.

ical order of the sources he used when it came to the relationship between Persian and Hellenistic writers. He read Kiesewetter's translation in a totally different context, namely, his own interest in tuning systems.[11] If the resulting argument could be considered as rather weak when seen from a philologist's point of view, it was strong in opening up a new methological perspective. Whereas Kiesewetter aimed at a philological investigation of sources, which was guided by his ideas about a European cultural and intellectual precedence over other musical traditions, Helmholtz relied on a practical understanding of tuning procedures that he had gained in his experimental work. This led him to reconsider the history of music theory as embedded in practices that involved hearing in ways that the experimenter could trace. For his concept of tuning, the idea that intonation could be "just"—in the sense of matching a certain ratio—was less important than the observation that such an intonation was "pure"—in the sense of avoiding distortion.

THE HARMONIUM AS A SITE OF EXPERIMENTATION

Helmholtz's brief paper on the Persian and Arabic scales provided no explanation for the leap from thirteenth- and fourteenth-century sources back to antiquity. Instead, he referred to the musical instruments used in Arabic and Persian music, arguing that Kiesewetter had ignored the fact that the quoted fragments concerned the use of the oud, the Arabic ancestor of the European lute. He wrote, "In Kiesewetter's study one finds the instructions that were given by Abdul Kadir and Schafieddin—Persian musicians of the fourteenth century—for subdividing the monochord and for fixing the frets of a lute."[12] Helmholtz seemed unconcerned about how frets could be reconciled with the idea of using pure fifths for positioning fixed frets.[13] Instead he posited that the late apparition of just thirds in Greek sources could best be explained from the Greeks' borrowing this interval from the Persian music which they were likely to have encountered by then. This hypothesis was based on three assumptions he implied about tuning more generally. First, a tuning process necessarily involved hearing. Second, the just third displayed the lack of beats that Helmholtz found to be characteristic

11. For a description of Kiesewetter's book and its merits as one of the studies of the music of a non-European culture group, see Philip V. Bohlman, "R. G. Kiesewetter's *Die Musik der Araber*: A Pioneering Ethnomusicological Study of Arabic Writings on Music," *Asian Music* 18 (1986): 164–96.

12. Helmholtz, "Ueber die arabisch-persische Tonleiter," 216. The typesetting quality of the proceedings is very poor in terms of typographic errors. This fragment literally reads "for fixing the ties to the pavilion," the date of the talk is indicated as the 32nd of May.

13. Figure 2 in Kiesewetter, *Die Musik der Araber*, between pp. 20 and 21, shows an oud with fret lines. On the early Persian predecessors of the lute, see Jean During, "Iran," *MGG Online*, accessed July 2, 2017, https://www.mgg-online.com/article?id=mgg15516&v=1.0&rs=mgg15516.

for consonances to a much lesser degree than the fourth, fifth, or octave. It was therefore unlikely that musicians would have noticed the specific qualities of the justly intoned interval when playing a lyre.

The third assumption was backed up by Helmholtz's own practice: a tuning system could be considered coherent when it was based on a well-defined procedure. Given the evanescent nature of sound, any procedure that could safely be handed on to others needed to be simple and consistent. It was common knowledge in Helmholtz's times that the Greek theory of harmony and proportion had favored the intervals constructed on the basis of the *tetraktys*, that is, the integers from 1 to 4. Only intervallic proportions built from these integers counted as consonant. The idea to consider epimoric (or superparticular) ratios—that is, proportions of two integers, one of which exceeds the other by a value of one—as a generative principle for musical intervals was, to the best of Helmholtz's knowledge, a matter of later times. The proportion 5 : 4, that is to say the just major third, first occurred in authors such as Ptolemy and Porphyry. Not only were they active roughly five centuries after the presumed origins of Greek music theory, they also lived in Alexandria and could have encountered the interval in a musical tradition that was different from their own. Finally, Helmholtz had no reason to assume that Greek tuning in fifths would exceed the steps that were necessary to tune a lyre, the instrument that was used in music teaching in Ancient Greece. The lyre required constant retuning and did not allow playing more than one pitch per string. The Greek sources favored *episteme* over *techne*: in other words, they did not describe tunign as a manual process, but instead indicated the reasoning behind the tuning or, in other words, the logos behind the intervals.[14] The Persian system, by contrast, was developed for the oud or one of its predecessors, instruments that allowed playing entire scales on each string. This raised the question of where to place the fingers (or frets), which, in Helmholtz's view, posed an additional problem of "tuning." Each string could be seen as a monochord on which the proper proportions had to be found. A tuning that concatenated a long row of fifths was easier to imagine on such an instrument. When Helmholtz reworked his talk to become part of the book *On the Sensations of Tone*, he therefore emphasized the independence of the Persian and Arabic musical systems from the alleged influence of European crusaders: "Hence the Europeans of those days could teach the Orientals nothing that they did not already know better themselves."[15]

14. Cf. Johannes Lohmann, *Musiké und Logos. Aufsätze zur griechischen Philosophie und Musiktheorie* (Stuttgart: Musikwissenschaftliche Verlagsgesellschaft, 1970).

15. Helmholtz, *On the Sensations of Tone*, 437.

So, for Helmholtz, the Greek and Persian tuning systems were based on different principles. The Greeks favored a principle of proportions that was expressed in numbers in the first instance, the Persians worked with a procedure that was based on reiterating a technical operation. Hearing took on a different role in both of these hypothetical tuning procedures. In the hypothetical Greek tuning, hearing was supposed to verify the correct application of the logos. In the (no less hypothetical) Persian tuning, the reiteration of a basic operation—the tuning of a pure fifth—yielded a result that the musician could judge with regard to its sound. In this way, a pure third could be reached without having a concept of such an interval.

The question of which instruments afforded specific tuning operations had occupied Helmholtz earlier. In the lecture on temperament, for instance, he wrote, "Not all instruments are equally sensitive with regard to dissonances. Singing voices are not subject to any tuning whatsoever, and in bowed string instruments only the tuning of the empty strings is. Here, the finely tuned ear of an experienced musician can avoid the worst harshness. The piano is insensitive towards dissonance, as its tones decay too quickly, and the organ is, due to the constant intensity of its tones, more prone to sweeping music with frequent use of dissonances than for expressive music with a soft sonority."[16] Certain distortions that Helmholtz found to occur in polyphonic music would therefore be more or less prominent, depending on the instrument one would play. Beats, combination tones and, most importantly, additional roughness due to combination tones, would be more prominent if an instrument produced sustained tones. If such an instrument were tuned according to an equidistant scale, or, in other words, equal temperament, this would lead to an annoying beating effect, that is, the intermittent increase in intensity resulting from slightly deviating frequencies, a phenomenon that Helmholtz compared to flickering light.

The harmonium, with its softer tones, was especially prone to being harmed by such distortions. The harmonium is an invention of the early nineteenth century. The instrument, marketed under various names, used freely vibrating metal reeds for tone production. As the reeds were most often activated from one and the same wind chest, strong nonlinear distortions affected the tone production. Helmholtz continued, "These disadvantages are particularly prominent in the . . . physharmonica. Due to its particular construction, combination tones are particularly strong in this instrument. The difference between purely intoned intervals and tempered intervals is so great that the latter appear to be dissonant, when hearing them after the former."[17] For

16. H[ermann von] Helmholtz, "Ueber musikalische Temperatur," *Annalen der Physik und Chemie* 113 (1861): 87–90, quote at 88–89.

17. Ibid., 89.

Helmholtz, these distortions pointed to essential features in the physiological process of hearing. The ear revealed its own activity in producing what one hears. Difference tones, or, in Helmholtz's terms, combination tones, could occur inside the ear, due to the smallness of the hearing apparatus in comparison with the sound waves. The fact that they could be heard even when no source outside of the ear produced them demonstrated the need of integrating physiology into any account of acoustics in the sense of the study of audible phenomena.[18] The beats resulting from a regular superposition of waves, in turn, occurred in any medium but would appear as beats only to the human listener, that is, a receiver with a fixed position in space. Aiming at an investigation of the activity of hearing as the transformation of vibration into nerve impulses, Helmholtz found valuable information about hearing in these distortions. The harmonium became an important tool in these investigations, as it made this sort of phenomenon particularly apparent.

In all of this, the actual transformation of vibrations into something audible remained inaccessible: Helmholtz could not observe the mechanical process he believed to occur within the inner ear *in actu*. All the more, beats and combination tones allowed an inquiry into the functioning of the ear by exploring the limits of its capacity. The fact that music featured periodic sound waves turned it into a relevant source for designing experimental setups. Even more importantly, Helmholtz could expect the aesthetic aims in music making to lead him to significant effects of distortion—or its avoidance—in music. Browsing through the history of music, Helmholtz hoped to find information on how musicians—that is to say, experts in hearing—had reacted to periodic sound. He used the harmonium to explore theory, composition and tuning systems. On the basis of such experiments, he inferred how musicians had used their hearing under different material conditions.

EXPERIMENTAL PHYSIOLOGY AND MUSIC HISTORY

An important factor in Helmholtz's experimental physiology was the application of his methodology to living objects. Experiments on living organisms tend to alter—sometimes even destroy—the objects experimented upon. Life always to some extent escapes our knowledge. If experimental work in the life sciences is often described as groping about in the dark, this can be related to its specific mode of experimentation. This mode requires series of experimental runs in order to get a better grasp of the

18. See Julia Kursell, "Wohlklang im Körper: Kombinationstöne in der experimentellen Hörphysiologie von Hermann von Helmholtz," in *Resonanz: Potentiale einer akustischen Figur*, ed. Karsten Lichau, Viktoria Tkaczyk, and Rebecca Wolf (Munich: Fink, 2009), 55–74, and "A Third Note: Helmholtz, Palestrina, and the Early History of Musicology," *Isis* 106, no. 2 (2015): 353–66; Hiebert, *Helmholtz Legacy*.

already acquired, and to be able to move on from there. Philosopher of science Friedrich Steinle has termed this the "exploratory" mode of experimentation.[19] Rather than the single *experimentum crucis* that is meant to dismiss or confirm the hypothesis in question, such an "experimental system," to use a term by Hans-Jörg Rheinberger, advances in small steps. This produces a series of data from reiterated runs of the experimental procedure.[20]

Most importantly, physiology and the life sciences more generally often cannot operate with a preconceived hypothesis. One could say that experimentation even seeks surprises. Using another term coined by Rheinberger, one could speak of the emergence of an "epistemic thing" in the runs of the experimental system. This terms denotes the moment in which a new knowledge item manifests itself and now becomes the actual object of investigation. During a short moment, this "thing" acquires agency: although the researcher cannot conceive as yet of the emerging model that explains an aspect of life to us—think of DNA or firing synapses—this model at some point appears in processes of experimentation. To make this possible, the technical aspects of each experimental run need to be fully under control, as the still unknown emergence cannot otherwise be traced and, in the following step, described. In the next round of reiterating the experimental system, this "thing" will change in status: it will be the new object of investigation that the researcher will try to explore further. It can even become a technical precondition for a new experimental design or, in Rheinberger's terms, a "technical object."[21]

In the case of Greek and Arabic scales, the concept of the "epistemic thing" might be used for the pure third. Helmholtz claimed that this interval was inconceivable to musicians in antiquity. He insisted that one would not find the third just by fiddling around with a lyre or even by extending the construction of epimoric ratios to further numbers. It was therefore not surprising that the third was considered a dissonance in the earliest testimonies of Greek music theory. Concerning the interval that the Pythagoreans used, that is, the interval that resulted from four steps of fifths, nothing hinted at specific acoustic properties. As a melodic step, in turn, the same Pythagorean interval was perfectly useful and necessary. It would thus hardly invite further exploration.

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19. Friedrich Steinle, *Exploratory Experiments: Ampère, Faraday, and the Origins of Electrodynamics* (Pittsburgh: University of Pittsburgh Press, 2016), and "'Das Nächste ans Nächste reihen'—Goethe, Newton und das Experiment," *Philosophia naturalis* 39 (2001): 141–72.

20. See Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, CA: Stanford University Press, 1997).

21. Ibid.

In contrast, the operation of tuning pure fifths on an instrument with several strings over a fingerboard, such as the lute or oud, could be expected to generate new tone relations. The very procedure of tuning fifths could be reiterated, and in repeating the procedure, it could bring an inconceivable object to the fore. Helmholtz's speculations suggest that the musicians used the lute for comparing notes. On a lute, it was possible to find one particular pitch through a comparison of notes on two strings and then retain it while looking for another particular pitch on two other strings. With the lyre, such a procedure was impossible to carry out. While all this remained purely speculative, it introduced a new methodological element into the study of music—the consideration of its material conditions.[22] Helmholtz's use of musical instruments in his laboratory had made him aware of the effects of such conditions. In his study of the ancient sources of music theory he reversed the situation, introducing a new type of evidence into the study of old texts.

CONCLUSION

On the occasion of the Fourth Congress for Experimental Psychology in 1911, philosopher Carl Stumpf and his colleague Erich Moritz von Hornbostel, head of the phonographic collection at the Institute of Psychology in Berlin, discussed the usefulness of ethnological work for psychology. The two speakers not only explained some of the reasoning behind recording music but also conducted an experiment with their audience. For this, they had brought a "metallophone" on which two equidistant (*gleichstufig*) scales could be played. Stumpf declared that one of them, which consisted of five equal steps, represented a "Javanese" scale, and the other, which was an equidistant heptatonic scale, a "Siamese" scale.[23]

According to Stumpf, nothing could have served them better to contest the widespread opinion that the European tonal system was the only system possible than these scales. Even though there was nothing natural or universal about scale systems, he continued, it was also inadequate to call these scales or the European tonal system "deliberately chosen." Scales and their uses interlocked, he explained, and neither side could

22. More recent literature on the early history of the modal systems in questions argues in a similar way. See, e.g., Habib Hassan Touma, *The Music of the Arabs* (Cambridge: Amadeus, 2003), 10, 17–22. Touma, however, also clarifies that Ṣafī al-Dīn al-Urmawī's system must be seen as a further development of Pythagorean tuning and was written under the influence of the author's knowledge of Greek sources.

23. C[arl] Stumpf and E[rich Moritz] v. Hornbostel, "Über die Bedeutung ethnologischer Untersuchungen für die Psychologie und Ästhetik der Tonkunst," *Beiträge zur Akustik und Musikwissenschaft* 6 (1911): 102–15.

stand on its own. For experimental psychology, he deemed one experiment he had conducted particularly important. Stumpf repeated the experiment with his audience:

> It is psychologically very interesting . . . to observe the reaction of our musical ear [*Gehör*] when one plays first the plates number 1, 3, and 5 and then the plates number 3, 5, and 7 of the Siamese scale. The ratios between all tones are exactly the same, but the first sequence of tones is mostly heard as a major chord and the second as a minor chord, because *c—e—g*, *e—g—b* are such. Someone who will, exceptionally, interpret the first sequence as a minor chord, will be likely to hear the second as a major chord—as corresponding to the triads in c-minor—*c—e-flat—g*, *e-flat—g—b-flat*. This is a blatant case of persevering memory."

The experiment demonstrated that music listening is very different from a simple reaction to physical occurrences. Two details were crucial in this. Both the scales and the sounds of the metallophone were unfamiliar to the audience. As they wished to observe listening in a fresh way, they deliberately employed sounds that were not immediately familiar to his listeners but that spoke to their musical experience. In this case, they addressed the familiarity with the sounds of the piano, whose short tones with a rich and noisy spectrum allowed for identifying the pitch that was required by a musical context, rather than a single measurable frequency.

This experiment is opposed to Helmholtz's use of the harmonium. Helmholtz favored the harmonium because it magnified the effects of mistuning and therefore enabled him to better control the material conditions of hearing. The object of investigation—in this case, the claims he found in ancient sources—was a tuning system. His experiment was aiming at the status of the just third: his speculation was based upon the assumption that this interval, once upon a time, had emerged as a kind of epistemic thing in the exploration of tuning systems on a lute. Stumpf and von Hornbostel, by contrast, were interested in cognitive phenomena and mental states. They inquired into the activity of the mind when it is confronted with musical sounds. Yet, in both contexts, it was the status of allegedly acquired musical knowledge that interested the researchers. Both experimental modes were primarily concerned to exploit the difference between music discourse and its material embodiments.

Javanese, Siamese, Persian, Arabic, and Greek scales do not enter this research as objects in their own right. Rather, one might call them "technical objects" in a context of experimentation. In the experimental setups described above, neither of these scales was more than a theoretical construct. Stumpf did not need thorough knowledge of Java and Ceylon to highlight (and challenge) the common assumption among his European audience that the diatonic scale was somehow natural, but he needed to be aware and in control of the properties of a metallophone's sounds. Equally, Helmholtz was hardly interested in Greek music (few examples of which are attested) per se. He wished to find out how something appeared that was otherwise inconceivable. Looking at this moment in the history of musicology, one is left with the fact that the exploratory mode of listening at work in these experimental contexts stood at the cradle of comparative musicology. The search for the living object that always remains to some extent inconceivable is perhaps what ties these beginnings most closely to the future development of the discipline—a discipline that, despite all its complexity, takes particular pride in admitting the inconceivable element at the heart of what characterizes the other as much as the self.

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