



## METHODOLOGICAL ASPECTS OF EARLY EXPERIMENTAL PHONETICS

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**Abstract:** The epistemological and methodological implicatures of experimental-phonetic research at the turn of the 19th and 20th centuries and in the following decades form a hitherto underdeveloped topic. The relevance of this focus stems from the innovative nature of experimental phonetics, which first had to assert its right to exist as an independent science in relation to adjacent fields, above all linguistics and psychology of language. Their claim to the field of speech science, which had been occupied for centuries by linguists, was explicitly defined by the early experimental phoneticians through their methods, of which a higher degree of objectivity and reproducibility of the results was expected. The experimental and data-based approaches formed the most important unique selling point of experimental phonetics compared to the treatment of the same subject in the work of linguists and speech psychologists. We want to show as well that the emergence of experimental phonetics is also due to a reorientation within linguistics in the last three decades of the 19th century.

### 1. Motivation

One of the subtasks of the BMBF cooperation project "Fascination Talking Machine" (2017 - 2019)<sup>1</sup> was the evaluation of the scholarly discounts retained by the Historic acoustic-phonetic Collection of TU Dresden, i.a. the written and photographic estate of Giulio Panconcelli-Calzia, one of the leading representatives of experimental phonetics in the first half of the 20<sup>th</sup> century. In this context<sup>2</sup>, it has become evident that methodological aspects of research, particularly the interactions between medical, linguistic, philosophical and scientific-theoretical approaches, which unite in the experimental-phonetic research, constitute a separate topic. In addition, we examined the interactions between experimental phonetics and contemporary linguistics based on a literature study. This seemed justified because, on the one hand, French linguists in particular, had decisively promoted the development of experimental phonetics, but on the other hand, the early experimental phoneticians insisted on a strict distinction between their field of research and the philological sciences.

### 2. Historical sources of experimental phonetics

It is well known that early experimental phonetics adopted not only scientific instruments but as well methodological knowledge and standards of empirical research from already established experimental sciences. From today's perspective, it seems that the boundaries between experimental phonetics and neighboring fields, first of all physiology, have been fluid for a period of several decades. Undoubtedly, multiple qualifications of some

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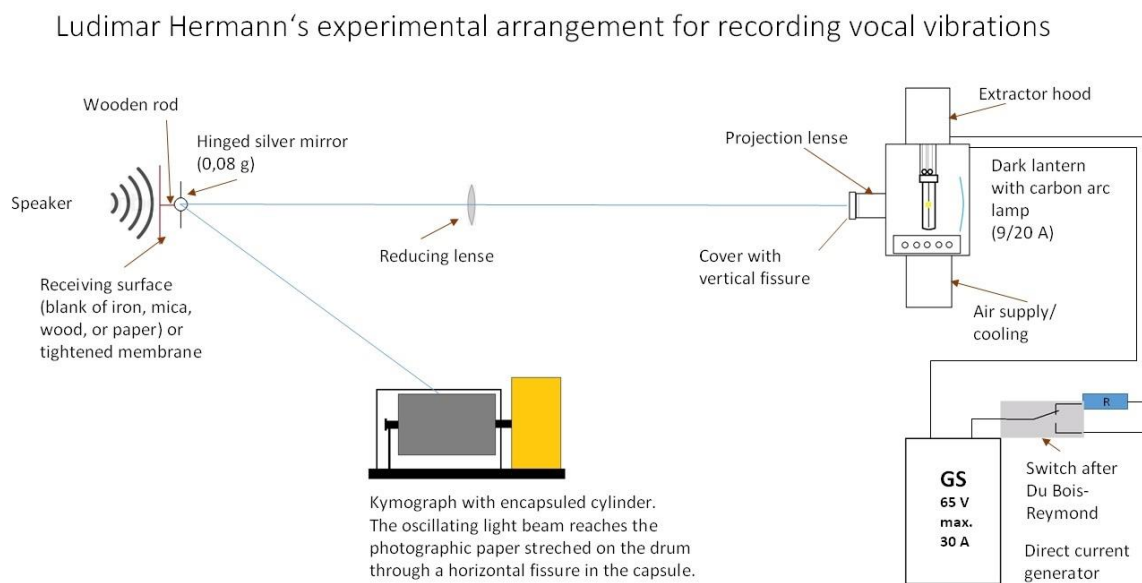
<sup>2</sup> Giulio Panconcelli-Calzia dedicated a number of books and articles to questions of methodology: [3], [4], [5].

researchers played an important role in disseminating research methods and scientific standards. Above all, medical, physical and mathematical approaches flowed into the experimental phonetic research practice. The technical equipment of the laboratories soon included the most advanced solutions in precision mechanics, optics, acoustics (sound recording) and electrical engineering available at the time.

### 3. Technical prerequisites for experimental phonetic research (using the example of Ludimar Hermann's "Phonophotographic investigations")

A prime example of the practice of the experimental study of speech sounds is the vocal analysis by Ludimar Hermann ("Phonophotographische Untersuchungen" [8]), published between 1889 and 1890 in "Pflüger's Archiv". Hermann recorded the vibrational graphs of sung and spoken vowels by means of a complex apparatus comprising a number of optical, mechanical and electrical components that conformed to the most up-to-date standards. The aim of the study was to prove the independence of the characteristic frequencies of the vowels from the fundamental frequency (Hermann coined the term 'vocal formants').

For reasons of space, we are content here with a drawing (fig. 1) that illustrates the detailed verbal descriptions in the text of the first part of the "Phonophotographical studies", and a list of the main components used with details of their origin or prototypes.



**Figure 1.** Experimental arrangement of Ludimar Hermann for the recording of vowel vibrations (compiled after the description in: L. Hermann: Phonophotographische Untersuchungen, Teil I. In: Pflüger's Archiv für die gesamte Physiologie des Menschen und der Tiere, XLV (1889), 582ff.

The main components used in Hermann's experimental arrangement for his "Phonophotographical studies" depicted in Figure 1 are:

1. Receiving surface (made of iron, mica, wood, paper), or strained membrane (similar to the recording membrane of a phonograph)
2. Hinged silver mirror (weight: 0,08 g), adapted from Thomson's mirror galvanometer (patented in 1858 by William Thomson /Lord Kelvin)

3. Projection lens with adjustable fissure (made by Dubosq/Pellin, Paris)
4. Projection apparatus (dark lantern) with carbon arc lamp (made by Siemens & Halske)
5. Switch with low bypass resistance (invented by E. Du Bois-Reymond in 1862)
6. Direct current generator (65 V)
7. Encapsulated kymograph (kymograph after Luwig & Baltzar with clockwork motor and centrifugal regulator, invented in 1846)

The vibration of the receiving membrane was transferred by a wooden rod to the mirror, which deflected a thin beam of light. The beam of light hit through a narrow horizontal fissure on the rotating drum of the kymograph that was covered with photo paper. The experiments were carried out in a perfectly darkened laboratory. Hermann obtained in this way very precise graphs, which he examined by Fourier analysis. For the rational implementation of the calculations, he developed calculation templates which made it possible to read out the relevant values in a very simple manner. Overall, he examined more than 4000 vibrational graphs. He came to the conclusion that the formant values of the vowels change with varying fundamental frequency only in relatively small limits. The importance of this work is acknowledged in detail in [10].

#### **4. Interactions between linguistics and experimental phonetics**

A historical investigation of the technical basis, the methods and the methodological principles of experimental-phonetic research must include not only the technological boundary conditions but also the interactions of experimental practice with developments in epistemology and methodology and the impulses emanating from other sciences. In the seventeenth and eighteenth centuries, the treatment of vocal articulation and the subsequent classification of the speech sounds and their integration into single-language and universal sound systems, regardless of the partly subjective and speculative approach, had already reached a respectable level (Wallis, J. 1653; Wilkins, J. 1668; de Brosses, Ch. 1765, Hellwag, Chr. F. 1771, v. Kempelen, W. 1791, cf. Pfitzinger & Niebuhr (2011) [9]). The emergence of experimental phonetics was the result of a long historical development and at the same time a landmark in the general transitional situation of the second half of the 19th century. The advance of quantitative methods and experimental procedures into traditional domains of the humanities began in the nineteenth century starting from such disciplines that have close relationships with physiology and observable behavior. Examples include psychophysics (E.H. Weber, G.T. Fechner, H. v. Helmholtz) and psychology (W. Wundt, H. Steinthal). Otto von Essen refers in his 1950 published article "The phonetic experiment and its importance for linguistic research" on a dating back to antiquity tradition of experimental research of voice and speech function [12]. As main protagonists of voice and speech research, he honors Galen and the Italian anatomists of the 16th and 17th centuries (Fabricius, Casserius). At least since Albrecht von Haller (1708-1777) detailed descriptions of voice generation and articulation processes were an obligatory part of all standard works on human physiology.

Wolfgang von Kempelen (1734-1804) is sometimes referred to as the first experimental phonetic scientist. In the course of his research on the development of the talking machine he carried out a number of investigations with mechanical vocal tract and excitation models [13: 80ff; 293ff.]. Systematic experiments with mechanical glottis models go back to the French scholars Jean-Baptiste Biot (1774-1862) and Charles Cagniard de Latour (1777-1859). "Biot and Cagniard La Tour sought to recreate the membranous lingual leaves of the larynx, the vocal cords, by elastic membranes of rubber stretched over a tube, thus making an artificial larynx" [14: 149]. The physiologist, anatomist and paleontologist

Johannes Müller (1801-1858) later improved the experimental setup by adding a model of the cartilaginous skeleton and the muscles of the larynx, which allowed him to vary the state of tension and the degree of approximation of the membranes. Johannes Müller published between 1837 and 1839 the hitherto most detailed studies on the mechanical, acoustic and physiological principles of action of the human vocal tract [14], [15]. The experimental data were obtained from anatomical specimens (combined with a mechanical tensioning device) and from artificial larynxes. Artificial larynxes of different construction with membranous tongues of rubber, arterial skin or frog muscles were also used by H. v. Helmholtz, E. Harleß and L. Merkel.

In addition to the physiological research on the object of the voice and the speech function, the registration of periodic processes was probably the most important prerequisite for the development of experimental phonetics. The recording of the time function of a vibration succeeded in 1807 the English physician and physicist Thomas Young (1773 - 1829), who is considered the inventor of the kymograph. The methodology of the kymography was perfected in the subsequent period, especially by the physiologists Carl Ludwig (1816 - 1895) and Étienne-Jules Marey (1830 – 1904). The special merit of Marey is the development of highly sensitive, calibratable mechanical transducers (Marey's capsules) that were capable of transmitting even the slightest pressure changes to a writing lever [16].

The Nestor of modern experimental phonetics and head of the world's first laboratory for experimental phonetics Abbé Pierre-Jean Rousselot (1846 - 1924) first published his two-volume work "Principes de Phonétique Expérimentale" [17] in individual deliveries in the years 1897-1908. Rousselot's significance is that he laid the methodological foundation of this innovative field of research and, during his time at the Catholic Institute in Paris and at the Collège de France, founded a school from which came some of the most important representatives of this discipline, including Hubert Pernot, Josef Chlumský and Jean Poirot, Giulio Panconcelli-Calzia, Théodore Rosset, George Oscar Russell and Raymond Herbert Stetson. The work of Rousselot as a pioneer of experimental research also extended to the field of vocal and speech therapy. Together with the ear, nose, throat specialist Marcel Natier in 1899 he founded the Institute of Laryngology and Otology in Paris. Hermann Gutzmann Sr., the founder of speech therapy as a university subject, had spent several months with Abbé Rousselot at the Collège de France before setting up his Berlin laboratory.

On the occasion of the opening of the Experimental Phonetics Laboratory at the Collège de France on April 10, 1897, the linguist Michel Bréal declared that phonetics could no longer be imagined otherwise than experimentally. The opening of the laboratory at the Collège de France marks the beginning of the institutionalization of the new field of research, whose development began around the mid-1870s, when French physiologist and inventor Étienne Jules Marey (1830-1904) set up a special speech research group in his laboratory, that included, besides him, the secretary of the Paris Société de linguistique Louis Havet and the doctor and deaf-mute teacher Charles-Léopold Rosapelly. The task consisted in the investigation of speech physiological phenomena by means of the "graphical method" founded by Marey, i.e. in recording movements of the speech organs as well as the pressure changes of the air stream in relation to the acoustic events. Rosapelly's work "Inscriptions de mouvements phonétiques" (1876/1877) marks the beginning of the application of experimental methods for the solution of linguistic problems and shows the fundamentally new possibilities of objectifying fleeting processes of speech production. Rosapelly's work took on a theme that was topical for the period at that time - the temporal synchronization of articulating gestures in nasal-plosive combinations in Sanskrit. Also within P.-J. Rousselot's school attempts were made to apply the experimental methods to questions of historical phonology, including a work on historical sound processes in the field of consonantism by Rousselot himself [3: 91].

Notwithstanding the fact that the early experimental phoneticists vehemently sought to distinguish themselves from traditional linguistics, a significant contribution to the establishment of experimental phonetics was made by French and German linguists, mainly by specialists in the field of historical-comparative linguistics. Michel Bréal, who made a decisive contribution to the establishment of the world's first laboratory of experimental phonetics at the Collège de France, saw the experimental method as an opportunity to oppose the overwhelming dominance of Germans in the philological sciences with a superior approach at the forefront of scientific and technological progress. "According to Michel Bréal, linguistics will finally be able to record facts instead of asserting principles a priori. There will be no more phonetics in vacuo, which - despite their extreme learnedness - uses technical terms to convey only misleading or vague ideas. (...) Thanks to the instruments of Edison and Marey we will be able to write the sounds - or rather they will write themselves, so that what the ear necessarily perceives only in a confused and fleeting manner, can be minutely and extensively examined by the face" (Des lois phonétiques.... Seite 11, cited after [18: 204]).

The interests of linguists had for decades been almost exclusively focused on the history of languages, more specifically on language change, language divisions and genealogical relations between languages, which have been demonstrated through historical-comparative studies using dead languages and past stages of living languages. The data used was almost exclusively written evidence. Phonological rules ("sound laws") allowed the reconstruction of missing links or prototypical forms. More or less implicitly an etymological identity or at least continuity of the roots was assumed, which was associated with a high degree of vagueness. The idea of a directed development passed through the entire era of the historical-comparative interpretation of language from Friedrich Schlegel to August Schleicher as a common thread. The basic idea was rooted in the idealistic philosophy of history (Schelling, Hegel) and found its way into the discourse on the origin and development of languages at the beginning of the 19th century. Another key point was Wilhelm von Humboldt's retrospective conception of language as a living organism that can only be considered from an evolutionary perspective [1]. To a certain extent, the humanities followed the previous development of the natural sciences: "... the crucial point that will brighten up everything here is the internal structure of languages or comparative grammar, which will give us entirely new insights into the genealogy of languages in a similar way as comparative anatomy has spread light over the higher natural history" (F. Schlegel 1808: „Über die Sprache und Weisheit der Indier“ [11, 28]). In order to clarify the initial situation (in the first half of the 19th century), some examples from phonetic or phonological descriptions of Gothic and Old High German in the "German Grammar" by Jacob Grimm [2] will be used in the following. From the fact that in the oldest runic inscriptions correspondences of the Old High German vowels e/ë are missing, J. Grimm concludes, based on etymological evidence, that these vowels evolved in Germanic languages from [a] (partly mediated by the Diphthong [ai]). Illuminative are furthermore different spelling variants for the same lexeme. From the fact that the vowels marked with circumflex in Old High German manuscripts were alternatively represented by double vowel letters, J. Grimm concludes that these are phonologically long vowels. The use of Greek borrowed diacritics (for example, by Otfrid of Weissenburg and Notker the German) provides information on the accentuation. Thus, J. Grimm concluded from the use of diacritics by Otfrid that the main (rising) accent in Old High German regularly met the first syllable. Additional accent information is provided by final rhymes. Varying writing of the vowels suggests tonelessness. J. Grimm concluded, e.g. from the varying spelling of certain affixes that the weakening of the secondary syllables was already widespread in Old High German. This assumption is also supported by frequent contractions of accented and weak syllables. Fluctuating spellings (in addition to diacritics)

also allow conclusions about the rising or falling nature of diphthongs. In the area of consonantism, certain combinations of letters indicate changes in the manner of articulation (for example, plosive + <h> as an indication of a secondary aspirate), double spells indicate geminates. Some scribes or writers transcribed phonological processes (assimilation, etc.). For example, Notker consistently reproduced not only the neutralization of the voicing contrast of obstruents in the final position, but also the devoicing of soft consonants (mediae) in the onset position after obstruents or at the beginning of the sentence. Despite the astounding wealth of phonological information that Grimm derived from writing, the researcher was aware of the limitations of his methods. The discovery of the Germanic sound shift by Jacob Grimm (Grimm's law) is probably due to the wealth of knowledge, the immense scope of the source material used by J. Grimm, and not least the intuition of the researcher.

What Hermann Paul wrote about the role of the instinct in the historical humanities seems to be particularly applicable to Jacob Grimm: "We merely deceive ourselves, if we think we can state the simplest fact in history without some accretion of speculation. Indeed, we always speculate, though perhaps unconsciously, and we have to set it down to a fortunate instinct if we hit the right mark. We may, very probably, maintain that hitherto the very methods of historical research in vogue have been discovered rather by instinct than by any manyside reflection penetrating the inmost essence of things" [7: xxvii]. Hermann Paul still states in 1880 that, in the absence of a methodological foundation that does justice to the subject matter of the history of language, it has not yet been possible to get beyond a mere juxtaposition of descriptive grammars of different languages and stages of linguistic development. By comparing linguistic realities in an abstract form, as provided by descriptive grammar, one does not obtain a history of language development that captures the causal relationships between successive phenomena (cf. [6: 19]).

In the introductory chapter of his "Principles of the History of Language", which was revised several times between 1880 and 1920, Hermann Paul states that there is an antinomy between experimental sciences and sciences of principles ("Prinzipienwissenschaften"). The task of experimental sciences consists in the determination of general laws that have timeless validity for a certain object under the same conditions. In this sense, he refers to the experimental sciences as to "sciences of laws" ("Gesetzeswissenschaften"). In contrast, a fundamental historical science, which Paul does not want to be understood as a philosophy of history, has the task of "lightening the conditions of historical development" and "to provide the methodological basis which has to be followed in the verification of every single fact." (see [6, 4]). Linguistics belongs to the sciences of culture, and thus also to the social sciences. In all sciences of culture operate psychological principles. However, the psychological approach to the study of language would lead to a one-sided view: "... no culture is possible on a purely psychical basis: and hence it seems, to say the least of it, very inaccurate to define the sciences of culture as mental sciences. (...) As soon as we enter the area of historical development, we have to deal with physical side by side with psychical forces. The human mind must always work in harmony with the human body and with its enviroing nature in order to bring forth any product of culture" (7: xxix). "The most important of the physical products which serve this purpose are precisely the sounds of language" [7: xxxviii]. Psychology and physiology are auxiliary sciences in relation to the history of language, the only auxiliary sciences that can contribute significantly to the explanation of the development of languages.

The real cause of linguistic change is nothing more than the ordinary speaking activity: "The changes in language fulfill themselves in the individual, partly through his spontaneous activity, by means of speaking and thinking in the form of language, and partly through the influence which each individual receives from others" [7: 15]. Discussing the reasons of phonetic changes, Hermann Paul emphasizes the physiological optimality of new pronunciation variants: "The reason why the inclination to deviation is greater on the one side

than on the other must be probably sought in the fact that the deviation towards the side to which it tends is in some respect more convenient. The examination of the nature of this greater or less degree of convenience is a purely physiological task" [7: 46]. H. Paul suggests, however, that the real deciding factor is motor feedback (the "motory sensation" associated by the speaking individual with a certain articulation). Relying on Eduard Sievers [19], he also emphasizes the role of the basis of articulation as a whole. Changes in one area of sound production usually result in corresponding changes in other areas.

In his "Foundations of Phonetics" [19], Eduard Sievers received the insights of the contemporary physiologists about voice and speech processes in an unprecedented scope and applied these findings to the subject of the historical phonetics and phonology.

In the works of the German Neogrammarians, especially Hermann Paul and Eduard Sievers on the subject of historical phonology, the turn to the speaking individual with its physiological and psychological characteristics is already emerging. The same tendencies can be observed in the contemporary publications of French linguists like Michel Bréal or Gaston Paris.

As shown above, significant impulses for the emergence of experimental phonetics, first of all the awareness of the need for research, came from the historical-comparative linguistics. On the other hand, the progress of physics and other natural sciences based on empirical, above all experimental research, facilitated the extension of physical methods and mathematical analyzes first to the field of physiology and in the following also to psychology. The work of mainly German and French physiologists of the 18th and 19th centuries formed the basis for the development of experimental phonetics as an independent discipline. "In particular, a variety of devices generated by experimental physiology and psychology were available. The stormy development of experimental phonetics was possible because phonetics was able to benefit from this fund - with certain adaptations "[20, 17].

The methodological awareness of experimental phonetics manifests itself above all in the instruments and procedures used, in constant struggle to improve them. The critical analysis of the performance of the recording equipment used, the care taken to calibrate it, and finally the ever-evolving measurement and evaluation methods, including the many innovations in metrology, are immense, from today's perspective.

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