

## Early Instruments in Auditory Research: The Lehmann Acoumeter

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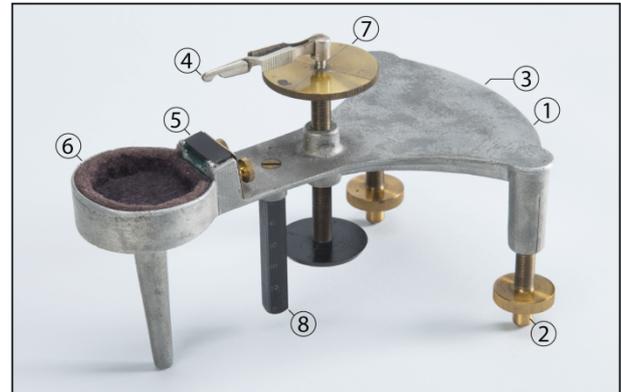
### Introduction

The Lehmann Acoumeter, an instrument developed in the late 19th century, was a tabletop device designed to generate impulse sounds of varying level. Compared to other purely mechanical instruments that evaluated hearing, e.g. tuning forks, sound pendulums, or a pocket watch, the design of the acoumeter was more sophisticated. An impulse was generated by dropping a steel pellet on a miniature glass plate. A pair of forceps, that are finely adjustable in height, were used to release the shot. In this manuscript, I highlight the design of the acoumeter and explore which niche it filled among the number of other acoustic instruments available at the time. The main hypothesis I propose is that because of the detailed instructions, the accuracy of the height adjustment, and the wide availability of the compact system (CH Stoelting Co. mass-produced the instrument), the acoumeter was an important step towards standardizing the measurement procedure of auditory tests. Because of the time commitment to determine one's hearing threshold using the acoumeter, it is unlikely that the instrument was used in clinical settings. Instead, it may have been used in laboratories that aimed to assess the hearing of study participants in preparation for, or for the use of psychophysical tests.

### Overview of the Acoumeter

I accessed an acoumeter from CH Stoelting Co. at the Collection of Historical Scientific Instruments at Harvard University, Cambridge, MA. The overall dimensions of the acoumeter are: 19 cm in length, 12 cm in width, and 12 cm height. Figure 1 highlights important parts of the instrument:

- 1) The corpus of the instrument is made out of cast iron.
- 2) The legs of the instrument are adjustable in height; the dials are made out of brass.
- 3) At the back of the instrument, a container is attached to store steel pellets.
- 4) Forceps are used to release a shot from a specific height.
- 5) The steel pellet lands on a receiving plate with dimensions of 10 mm x 5 mm x 2 mm. The receiving plate is slightly angled to constrain the fall of the pellet in forward direction.
- 6) After the pellet is released from the forceps and generated sound from the impact on the receiving plate, the shot lands in a felt-lined container to avoid echoes of the acoustic impulse.
- 7) At the center of the instrument a large brass dial with a diameter of 4.5 centimeters is located. The dial is connected to a threaded rod and allows the user to adjust the height of the forceps. A full revolution of the dial corresponds to a change in height of 1 mm.
- 8) A scale bar of 50 mm length (marks every 1 mm) is attached to the underside of the instrument; it allows the user to read of the height of the forceps with respect to the receiving plate.



**Figure 1:** Overview and important landmarks of the Lehmann Acoumeter. The detailed descriptions of number 1-8 may be found in the text.

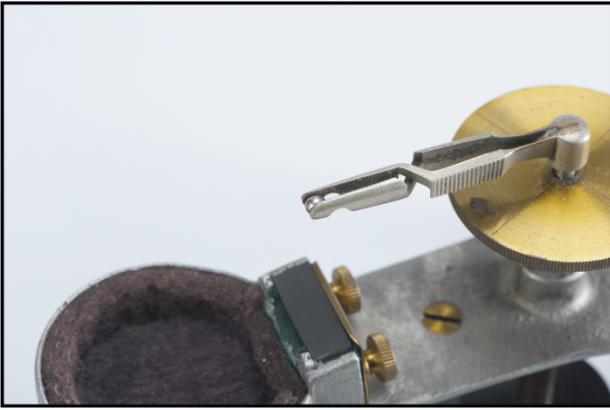
### How was the Instrument Used?

I distilled the information of the use of the instrument mostly from a manuscript from Davis and Merzbach, published in the Smithsonian Institution Press (1975) [1]: The instrument was placed on the desk of the experimenter and the legs were adjusted to level the instrument. The test subject was seated 10 meters away from the instrument. In order to avoid visual bias, the subject was seated with the back to the instrument or was asked to close her eyes. The mouth of the test subject was ordered to be closed during the experiment, possibly to avoid artifacts from a patent Eustachian tube. To evaluate the left and right ear separately, one ear could be plugged for the duration of the experiment.

The instrument was delivered with different receiving plates to alter the overall level of the impulse sound. The receiving plates were made out of glass, copper, and cardboard. If only one receiving plate could be used, it was recommended to use the glass plate. For the instrument I examined, the cardboard and copper plates were missing.

The instrument was used to determine the hearing threshold of the test subject. Therefore, a steel ball was released from the forceps (see Fig. 2) and the subject was asked to report whether or not she heard the impulse sound. The experimenter conducted at least 10 trials with the code word "NOW" before she released the steel pellet from the forceps. In order to test whether the participant answered correctly, a number of "empty runs" could be performed, where no shot was dropped after the code word.

If the sound of the steel pellet was clearly audible to the test participant, the height of the forceps was lowered with the brass dial. Special instructions were provided to ensure a time-effective conduct of the experiment: It was recommended to use the thumb and middle finger of one hand to operate the brass dial to adjust the height of the forceps and to use the thumb and index finger of the other hand to operate the release mechanism (forceps). The hand used to operate the forceps was used to place a new steel pellet into the forceps. After each run, the height of the



**Figure 2:** Release mechanism of the steel pellet. After opening the forceps, the shot falls onto a receiving plate and into a felt-lined catch basin.

forceps was lowered by half a turn of the brass dial (0.5 mm) until the “critical height”, i.e. the height of the forceps where the impulse sound of the impact of the steel pellet onto the receiving plate was no longer audible for the participant, was determined. Eventually, the height just above the hearing capability was reported. Thus, the units in which hearing thresholds were measured were millimeter.

The height adjustment works in two steps: First, the height of the forceps can be adjusted by means of the brass dial, which holds the forceps. One revolution of the brass dial corresponds to a change in height of one millimeter. The tick marks on the brass dial indicate a quarter revolution, corresponding to a height change of 0.25 mm. This allows a very fine control over the height and helps the experimenter to change the height of the forceps without looking at the absolute values of the scale bar at the bottom of the instrument. The ticks on the brass dial that indicate relative height changes likely helped to accelerate data collection. Second, a fine-adjustment mechanism is found within the forceps (see Figure 4). This allows adjusting the height of the forceps within micrometers. The fine adjustment was probably used after the receiving plate was changed. In order to calibrate the height from the receiving plate, the gross-adjustment using the large brass dial was brought to 0 mm; the fine-adjustment mechanisms could then be consulted to assure a “true” zero-height from the receiving plate.

### Who used the Instrument?

The instrument was probably used only in research studies and not in clinical settings. The most compelling reason to me is not that the operating of the instrument requires some training, but that a test to determine the hearing threshold can be lengthy. Furthermore in clinical settings, in the 19<sup>th</sup> century as well as today, the exact value of the hearing threshold (or loss) is not of great importance. Even today, hearing threshold are only determined within 5 dB. Thus, a precision instrument like the acoumeter was likely used in research studies, where the exact determination of the hearing threshold was of great interest.

The instrument was likely used in laboratories that aimed to access the hearing of study participants. I have found no evidence that the instrument was commercially used (i.e. by medical professionals). I estimate the time commitment to determine the hearing thresholds to at least a



**Figure 3:** Fine-adjusting mechanism. The set screw was used to calibrate the height of the forceps.

few minutes. Furthermore, for clinical purposes the hearing threshold to a click-sound is less informative than measuring hearing thresholds to pure tones, such as obtained by using tuning forks. The time commitment to conduct this experiment and frequency-unspecific stimulus of an impulse sound are reasons why the instrument may have been used in research settings rather than in the clinic.

### Discussion

In the second half of the 19<sup>th</sup> century psychological (and psychophysical) research underwent an enormous boost with Gustav T. Fechner’s formulation of Weber’s law and Fechner’s law. It is not surprising that during that time period special instruments were developed to cover only one specific task; in the case of the Lehmann acoumeter to measure hearing thresholds to impulse sounds. Companies like CH Stoelting saw the potential of making instruments like the acoumeter (and many other instruments) commercially available and provided detailed instructions, which contributed to standardized measurement methods across the globe.

### Acknowledgements

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### Literature

- [1] Davis, A.B. and Merzbach, U.C: *Early Auditory Studies*. Smithsonian Institution Press (1975)
- [2] Klang, B. *Experimental Psychology, A Manual of Laboratory Practise, Volume 2*, The MacMillan Company, 1905