Why Was Your Hearing Tested: Two Centuries of Progress

Robert Ruben

Introduction

Today, almost every human being in the developed world and many in the rest of the world will have the opportunity to have their hearing tested from birth until old age. Testing, however, depends on interrelated factors including (1) the awareness of hearing loss; (2) the development of tools to test hearing; (3) knowledge of the causes of hearing loss; (4) the ability to intervene to restore or prevent further hearing loss; and (5) the development of devices to compensate for hearing loss.

Individuals undergo a hearing evaluation to determine whether a hearing loss is present and, if so, how great a loss; to determine the nature of the disease causing the hearing loss; and to provide a basis for determining whether there was further hearing loss due to environmental noise.

Although hearing loss has no doubt been ubiquitous in human populations, particularly with aging, testing for hearing loss and efforts to mitigate these losses are relatively recent. Indeed, the assessment of loss is only a few centuries old. The purpose of this article is to share some of the history of the evaluation of hearing loss, demonstrating that doing so is complex, but it has involved some of the leading "stars" among hearing researchers.

Before 1801: Qualitative and Subjective Assessments of Hearing Using the Human Voice

Anatomical and clinical writings that concerned the ear and hearing before the beginning of the nineteenth century did not address evaluating the hearing of most individuals. There was the awareness that hearing could come through bone conduction (the conduction of sound to the inner ear through the bones of the skull) that had been known since the sixteenth century as illustrated in the frontispiece of Bulwer's *Philocophus* (1648) (**Figure 1**). Bone conduction was observed in patients by Du Verney (1683), who noted that some hearing-impaired people would hear much better when the end of the vibrating instrument was held in the teeth and did not depend on hearing coming through the external auditory canal. He also diagnosed the blockage/closure of the external auditory canal as an anatomical site of the hearing loss.

As late as 1801, hearing ability was assessed by the subjective and qualitative perceptions of the patient and the physician as noted by Cooper in evaluating the results of his surgical intervention.

> "A woman about thirty-six years of age consulted me, in December last, respecting some disorder in her child. In attempting to converse with her, I found her so extremely deaf that it was with difficulty I could make her hear me... I immediately punctured the membrane of the left ear, being that in which the hearing was most defective. The operation was no sooner performed, than, to my great joy, and of course to hers, I found that, in that ear, she could hear what 1 said to her, without any particular exertion on my part to speak loud. She staid with me about half an hour; and, when she left me, was capable of hearing every thing that was said in the ordinary tone of conversation" (Cooper, 1801, p. 441).

1802 to 1921: Quantitative Measures of Hearing Ability Using the Human Voice and Physically Generated Sounds

Children

The earliest quantitative assessment of hearing was carried out in deaf children to determine if therapy improved their hearing. The first was by Wolke (1802), who developed an instrument to ascertain whether there was any improvement in the hearing of deaf children after they

©2021 Acoustical Society of America. All rights reserved.
https://doi.org/10.1121/AT.2021.17.3.40

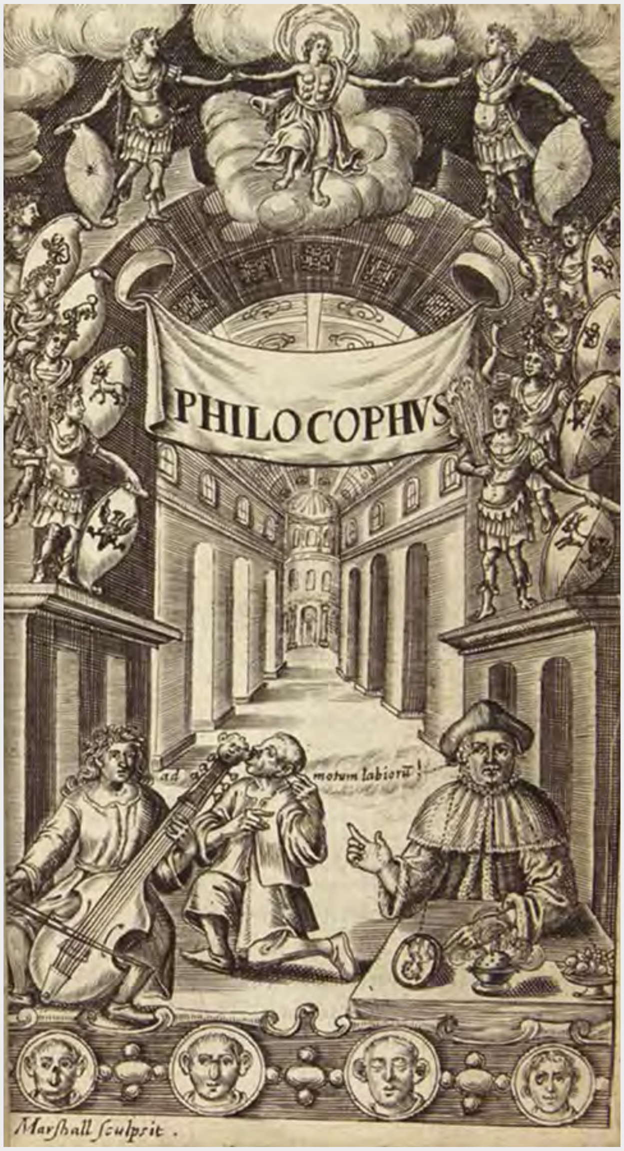


Figure 1. Philocophus *or* The deafe and dumbe mans friend *(Bulwer, 1648). This is the frontispiece of this work, which is the first known representation of bone conduction.* ***Middle left:*** *man next to the cello "listening" to the cello with his teeth to illustrate bone conduction.* ***Middle right:*** *effects of speech articulation by blowing smoke.* ***Bottom:*** *four faces (****left to right****): The first head shows a man with his mouth not in the normal position but located in the middle of the nose (smell), meaning that he can taste through his nose. The second man lacks a nose, and his mouth is shifted to the area of his nasal root, meaning that he can smell through his mouth (taste). The third man is blind; however, in each auricle an eye is engraved, thus he is able to see with his ears. The man on the right has no ears, but he hears with the right eye that is shown by an auricle replacing the eye (Pirsig and Stephens, 1994, p. 115). From the author's collection*

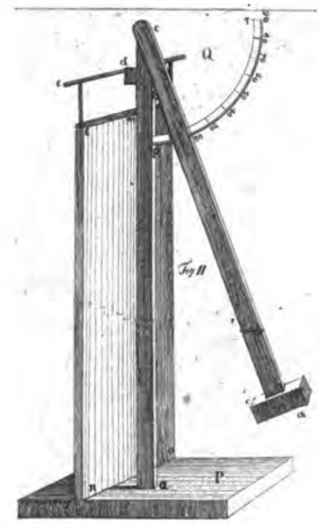


Figure 2. *Wolke's acoumeter was a wooden board (n, o, c, m,) placed upright. Attached to it was a drumstick (c, ch), which was dropped onto the board from various heights as measured by the protractor (Q) that determined the amplitude (Wolke, 1802).*

were exposed to electrical auditory stimulation. Wolke's work was based on the observations of Volta and many others (reviewed by Marchese-Ragona et al., 2019). Wolke's (1802) instrument, an acoumeter, was a wooden board placed upright, attached to which was a drumstick that could be dropped onto the board from various heights as determined by a protractor (**Figure 2**) that measured the amplitude of the sound. Itard (1821) described a similar instrument made of metal for ascertaining whether or not there was improvement in the hearing of deaf children after hearing exercises using voices.

School Screening

It was long recognized that school children with a hearing impairment would be at a disadvantage in learning and would often be considered mentally retarded. Blake (1876), a physician, recognized the need to determine which children had a hearing loss and created a screening program for school age children. Each child would have his/her hearing assessed by recording his/her ability to detect speech at a fixed distance from the teacher. The teacher spoke a proscribed series of test words based on the work of German investigator Wolf (1871) that were selected for the way in which they are affected by a hearing loss. If a child was found to have a hearing deficit, provision was made for the child to be positioned within the classroom so as to optimize his/her ability to hear what transpired. The child would also be seen by a competent medical person for care. This semiquantitative technique was only occasionally adopted during the next 45 years but was used for a time in Boston and New York City schools.

The need to identify the hearing-impaired school child was recognized in the United Kingdom in a report of the Chief Medical Officer to the Board of Education (1910) of London, UK The report noted that 3-8% of all the elementary school children in England and Wales had some form of defective hearing, noted the need for the testing of children, and stated that there was a lack of precise and consistent means to accomplish this. The report used a variety of different tests and felt that the best was the use of whispered speech for which there was no control of amplitude or content and consequently varied within and between tests.

Medical

During the first half the nineteenth century, children had their hearing assessed by asking them to listen to speech or the ticking of a watch. This was carried out primarily when the physician thought there could be occlusion of the external auditory canal by cerumen (ear wax) or foreign bodies or exudate (fluid) in the middle ear and then to determine the amount of hearing remaining in children who were considered "deaf and dumb" (Toynbee, 1860). The hearing assessment for occlusion of the external auditory canal was used to document the success of the intervention, that is, removal of the wax. One study of 411 children examined at the Deaf and Dumb Asylum found that three-fifths did not hear any sound, whereas the remaining children heard certain sounds such as repeating short words or the clapping of hands.

Tuning forks became part of the diagnostic pediatric armamentarium in the 1870s to differentiate between hearing loss from a conductive defect in the transmission of sound to the inner ear and a sensory hearing defect in the transduction of sound by the inner ear to the central nervous system. The knowledge of various tests for conductive and sensory hearing loss was well-known and extensively utilized by the beginning of the twentieth century.

Using tuning forks testing for children was challenging. Politzer (1902a) developed a very simple instrument called the acoumeter (**Figure 3**) that allowed for diagnosing a qualitative type of hearing loss as conductive or sensory loss and allowed for differentiation of diseases of the external or middle ear and, to a much lesser extent, of sensorineural loss. The testing allowed for the application of the then known effective medical or surgical interventions.

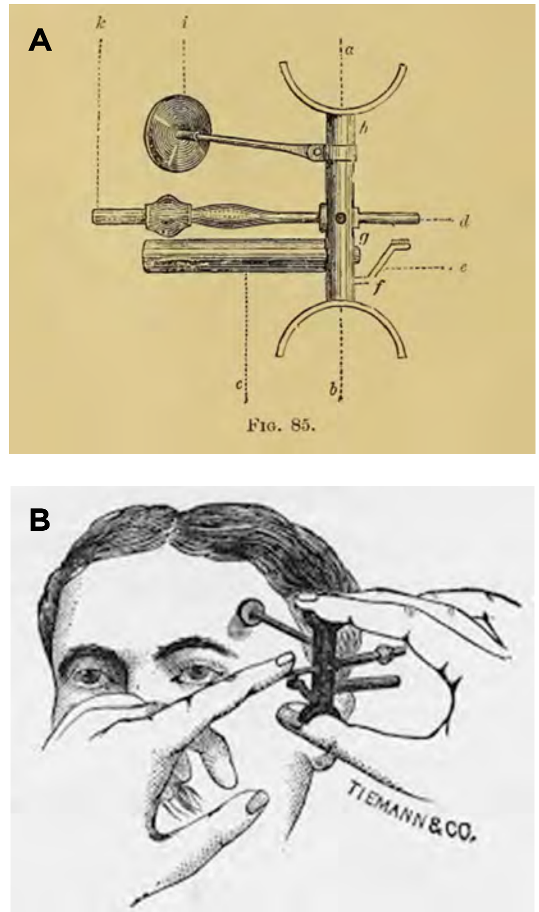


Figure 3. ***A:*** *Politzer acoumeter consisted of a horizontal steel cylinder (c) 28 mm long and 4.5 mm thick, connected with a perpendicular vulcanite column (h, f) by means of a tight screw. A percussion hammer (k, d) is attached above the place of attachment of the steel cylinder. This is movable on its long axis and produces the tone by falling on the steel cylinder. The device is rotated, h, so that the circular piece, i, is placed perpendicularly on the head and k, d is dropped against c which creates a sound that can be heard through air and bone conduction (Politzer et al., 1903). From the author's collection.* ***B:*** *application of the Politzer acoumeter in a subject (Winslow, 1882).*

Adults

Medical

Most of the otologic disease entities known in the twenty-first century had been defined during the nineteenth and early twentieth centuries. Parallel to this increase in knowledge was the advent of successful interventions, primarily surgical, for these various conditions. The knowledge of and the effective ways to care for ear diseases required an objective means of diagnosing and evaluating the outcomes of care.

During the nineteenth century, there was the significant development in the science of acoustics, most notably the work by Helmholtz (1863). The otological textbooks of this period emphasized that a requirement for evaluating the patient was to obtain a measure of the patient's hearing using speech as a qualitative measure. The more quantitative measures were through the use of tuning forks. Several standard utilizations of the tuning fork test were found in the texts then and now.

One such test was known as Weber's (1834) test. In this, a 512-Hz tuning fork is placed on the forehead. The patient then reports in which ear the sound is louder. When the patient reports hearing the sound equally in both sides, it is considered normal. When one ear hears the tuning fork louder, this is the defective ear.

Rinne's (1855) test used a combined testing of air and bone conduction. The normal ear, therefore, hears the tone of the fork longer through the air better than through the cranial bones.

Screening

The first documented screening for hearing in an adult population was carried out by the German military in 1888. Individuals who were being considered for military service were classified so that those with normal hearing were sent to the front and the others served behind the lines (Dölger, 1927). Then, at the beginning of the twentieth century, hearing screening was established for military service in the United Kingdom and the United States.

At the beginning of the twentieth century, deafness of either ear constituted an absolute cause of rejection to serve in the United States Army. The testing criteria were qualitative.

> "As the distance at which the natural tone of voice may be heard in a closed room, when both ears are normal, is about 50 feet, the distance at which the applicant is to stand from the examiner must be as great as the apartments will allow, not to exceed 50 feet. The applicant will stand with his back to the examiner, who is to address him in a natural tone of voice. When the distance is less than 40 feet, it should be specified on the examination form, and the tone of voice will be lowered. Failure of the applicant to respond to the address of the examiner will demonstrate a defect" (Politzer, 1902b).

The earliest workplace hearing screening for civilian employees was conducted by railways. These were developed as a result of a series of accidents that appear to have occurred because the engineers, the drivers of the train, had a hearing loss. At the end of the nineteenth century, the European railways had established hearing screening for their employees that held positions in which good hearing was essential for safety. The railroad companies also acknowledged that rail service could cause hearing loss and therefore part of their program was to have periodic examinations of the hearing of the critical railroad workers. Politzer stated:

> "As many disturbances of hearing develop only during the time of service, such examination would seem of value, in the author's opinion, only if needed at regular fixed intervals. It may, however, be stated with satisfaction that most of the companies have given attention to this proposition" (Politzer, 1901).

Malingering

The increased attention to hearing ability by health workers, industry, and the military resulted in some individuals pretending, malingering, that they had a hearing loss. Some of these were individuals with psychiatric difficulties, others wanting to avoid perilous military service, and others wishing to be employed or remain employed.

As a consequence, a series of tests were developed to detect malingering. One method is the use of the Bárány noise machine. The noise is applied to the purported affected ear, and the patient is then required to read a passage. If the patient raises his/her voice with the noise, then one assumes that the ear being masked is functional because the patient can hear the noise. If there is no change in the volume of the reader's voice, it indicates that the ear subjected to the noise is hearing impaired (McKenzie, 1920).

Figure 4. *The Western Electric 1A audiometer. Available at acousticstoday.org/WE1aaudiometer. Accessed March 14, 2021 and April 15, 2021.*

1922 to the Present: Quantitative Measures of Hearing Ability Utilizing Psychophysics and Physiology

Beginning in the twentieth century, the development of electronics, primarily based on the vacuum tube, resulted in the creation of electronic-based instruments for testing hearing, the audiometer. These were originally reported in 1921 in Germany (Feldman, 1979). In 1922, the Western Electric Company (Fowler and Wegel, 1922) in the United States introduced the 1A audiometer that became the model for subsequent commercial instruments (**Figure 4**). The use of the audiometer to establish hearing ability in patients rapidly became the standard of practice throughout the world.

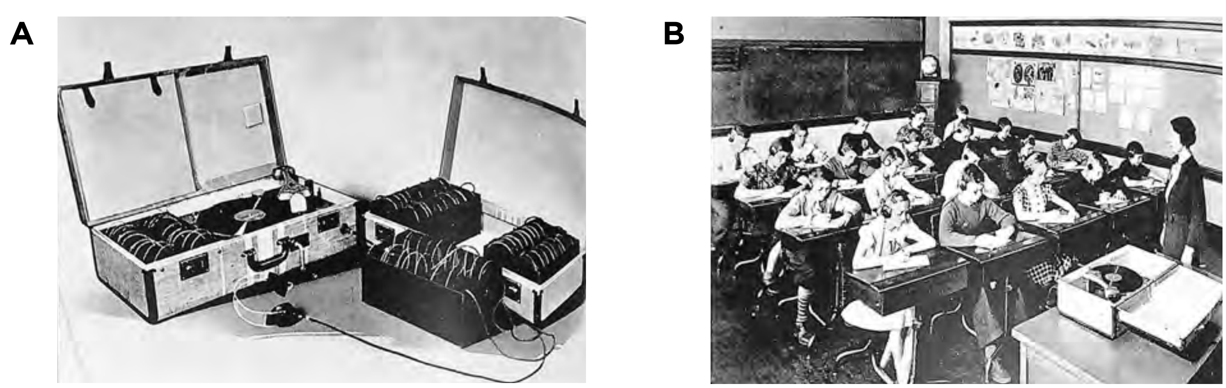
Children

The advances in electronics were applied to mass screening of children. **Figure 5B** shows a school class being tested with the equipment in **Figure 5A**. Several devices using a phonograph to control the stimulus that was distributed to a classroom of pupils through earphones was utilized through schools primarily throughout North America and Europe. **Figure 5A** shows the equipment used to test multiple children simultaneously. Fletcher (1929) stated that: "It is estimated that approximately 1 million have now been tested with this instrument..." By the 1940s, almost all schoolchildren in North America and Europe would have their hearing tested.

Screening for hearing loss in newborns was considered to be critical for the optimal development of the child. In 1944, British investigators Ewing and Ewing articulated the need for some means to test newborns, but with a comprehensive survey of the literature, they could not identify any way to carry this out. Fisch (1957), also in the United Kingdom, noted the need for a newborn/infant screening system and described what became to be known as a high-risk registry for identifying infants at risk for substantial hearing loss:

> "Screening of children with unknown possible cause of hearing loss their history is more practical... If

Figure 5. ***A:*** *4B phono audiometer complete with four receiving trays and carrying case.* ***B:*** *testing school children's hearing using telephone headsets with the 4B audiometer (Fowler, 1947).*



there is a history of deafness in the family; if a child's mother had rubella or any other virus disease during a critical stage of pregnancy; if the child suffered from anoxia at birth of apraxia in a premature child, or the labor was unusually protracted, and the delivery was complicated; if a child had hemolytic disease of the newborn or was jaundice as result of premature birth mature birth or had kernicterus, in all these cases the offspring should be tested without exception at the appropriate time" (Fisch, 1957, pp. 233-234).

Hardy (1965) presented the details for a similar high-risk registry. During the next two decades, the high-risk registry was utilized but was only able to diagnose 50% of the affected children. These findings are summed up in the US National Institutes of Health Consensus Development Conference Statement (National Institutes of Health, 1993). By 1993, screening was dependent on the high-risk registry and some applications of the physiological tests: auditory-evoked potentials and otoacoustic emissions.

These objective quantitative assessments of hearing ability came about in the last half of the twentieth century through the application of physiological aspects of the auditory system to the diagnosing of hearing impairments in patients. These were the recording of the cochlear microphonic in humans (called electrocochleography) (Ruben et al., 1959), application of middle ear admittance to the diagnosis of middle ear pathology (Terkildsein and Thomsen, 1959), recording of auditory brainstem responses (Jewett and Williston, 1971), and the discovery of otoacoustic emissions (Kemp, 1978). These physiological assessments had a significant role in the establishment of hearing loss in patients who could not communicate whether they perceived sound. The most widespread use of these techniques was in the establishment of hearing loss in newborns and young children.

The application of the physiological advances, including measurements of the auditory brainstem response and evoked otoacoustic emissions, was first clinically applied to the testing of newborn infants and reported by Kennedy et al. (1991). A combination of physiological tests consisting of automated otoacoustic emissions and automated auditory brainstem response was utilized. In 1994, Hunter et al. reported on their two-stage universal screening test of 213 infants at a large district maternity hospital in the United Kingdom. They found that a two-stage screening protocol, first otoacoustic emissions and then, after the failure of otoacoustic emissions, an auditory brainstem response, to be the most effective.

White et al. (1993, 1994) reported their results of the two-stage screening program on infants born at Women and Infants Hospital of Rhode Island. They concluded:

> "Based on a relatively large sample of 1850 infants from a WBN [well-baby nursery] and a NICU [neonatal intensive care unit], this study provides evidence that (1) hearing impaired infants can be identified based on a TEOAE [transient evoked otoacoustic emissions] screening protocol and (2) many of those infants would not have been identified using the currently recommended approach of screening only high-risk children" (White et al., 1993).

White et al.'s results were confirmed in a New York State study carried out from 1995 to 1997 that included infants from diverse social, economic, and cultural backgrounds. There were 69,761 infants evaluated from 7 different regional perinatal centers (8 hospitals) representing various socioeconomic regions. All the hospitals utilized the two-tier system rescreening both in the well-baby nursery and in the neonatal intensive care units.

The two-step newborn infant hearing screening program is now a standard procedure for all newborn children in the United States (Centers for Disease Control and Prevention, 2019). The screening program has also been widely adopted in Europe. Throughout the world, it has been utilized by many but not all countries and modified in some to meet their economic, cultural, and geographic needs (Neumann et al., 2019).

Adults

Hearing loss as a consequence of exposure to noise in the workplace has been long recognized. The earliest reference to deafness resulting from exposure to noise in the workplace was published by Ramazini (1700, also see 1964) where he described hearing loss and workers in a flour mill. In his second edition in 1713, Ramazini describes the effect of ironworkers in the ghetto in Venice who, after working there for many years, became deaf.

> "From this quarter there rises such a terrible din that only these workers have shops and homes there but all others flee from the highly disagreeable locality... To begin with, ears are injured by that perpetual din,

> and in fact the whole head, inevitably, so that workers of this class become hard of hearing and, if they grow old at this work, completely deaf" (Ramazzini, 1713, 1964).

There was no compensation by industry for hearing loss until 1948 when the New York State Court of Appeals upheld the decision of the Workmen's Compensation Board to award Mr. Slawinski $1,661.25 for his hearing loss he worked for J. H. Williams and Company. The court stated that hearing loss due to industrial noise is an occupational disease and that there may be a compensable disability in an occupational disease even without any loss of earnings. This ruling was rapidly advanced throughout the United States, with multiple lawsuits resulting in compensation for industrial noise-induced hearing loss. This resulted in required standards of preemployment and employment hearing testing. The Occupational Noise Exposure Revised Criteria (National Institute for Occupational Safety and Health, 1998) for audiometric evaluations of employees required that a baseline audiogram be obtained at inception of employment, monitoring audiograms with retest audiograms conducted periodically during employment, and an exit audiogram taken at the termination of the worker's employment. The Occupational Safety and Health Administration (OSHA) has specified the length of time an employee can be exposed to sounds of various intensities, the details of programs for monitoring the hearing of employees, specifications for the equipment used for the monitoring of employees, and the use of protective gear and/or engineering controls (OSHA, 2021a). Now, many workers have multiple hearing evaluations while employed in industries with noise exposure, and the industries are required to have conservation of hearing programs (OSHA, 2021b).

Geriatric

The wide recognition of hearing loss in the aging population, presbycusis, has come about during the twentieth and twenty-first centuries. Concomitant with this has been the availability of accurate hearing testing, either in a facility or through the Internet. This quantitative documentation has allowed for the use of hearing aids. Hearing aid sales in the United States increased by approximately 750,000 in 1980 to more than 4,230,000 in 2019, a 5.6-fold increase (Hearing Review, 2021). This increase implies a similar increase in the number of hearing tests carried out. One could estimate that for each hearing aid, there was at least one, if not two or three, hearing tests carried out before the hearing aid was actually utilized by the patient.

Hearing loss in the elderly has been associated with psychiatric illness (Eastwood et al., 1985) and diminished quality of life (Carabellese et al., 1993). Other studies have shown a correlation of presbycusis with mortality (Lam et al., 2006). A small study of eight patients with Alzheimer's disease with hearing loss found that from one to four problem behaviors were significantly reduced for each patient after hearing aid treatment (Palmer et al., 1999). A study of depression in the elderly with hearing impairment showed that providing hearing aids had a significantly positive effect on the patients (Metselaar et al., 2009). These findings demonstrate the need for a geriatric hearing screening program.

Insofar as can be determined worldwide, no systematic hearing screening programs of the elderly are in place. The need for geriatric hearing screening will become even greater as the population ages. This history has yet to be written.

Conclusions

Three questions have been addressed in this article.

(1) Why would you have a hearing test? Since 1800 to the present, people were tested to determine if they had a hearing loss; to determine where the problem, the disease entity, was that caused the hearing loss; to determine the extent of their hearing loss; to determine an intervention to ameliorate their hearing loss; to establish their fitness to serve in a particular role in an occupation or military service; and to protect them from further hearing loss due to sound trauma in the workplace.

(2) Who had a hearing test? Everyone from the newborn to the aged was tested. The first hearing test was in the newborn intensive care unit or nursery. The last hearing test was when one is aged to provide for a hearing aid that would not only help in communication but also as a way of mitigating some of the cognitive deficiencies of aging.

(3) How was your hearing tested? This started out with a voice test that was qualitative; Then there was and still is the use of tuning forks that was qualitative but allowed for localization of the disease; advances

in electronics such as the audiometer that allowed for quantitative descriptions of hearing loss over frequencies; and, most recently, application of the physiology of acoustics for the objective measure of hearing ability of the patient.

Finally, in this article, I have tried to give the flavor of the history of hearing testing. Such testing has proven to be a substantial medical advance for humans from babies to the very old. In each case, the purpose has been to improve the quality of life that comes from being able to communicate effectively with sound. This gains upmost importance in the postindustrial era where most occupations in our communications-based economy require optimal communication, which is dependent on good hearing (Ruben, 2000; Bureau of Labor Statistics, 2021).

References

Blake, C. (1876). On the best mode of testing the hearing of school children and providing for the instruction of partially deaf children. In J. Asshurst, Jr. (Ed.), *Transactions of the International Medical Congress of Philadelphia*. Collins Printer, Philadelphia, PA.

Board of Education (1910). Report of the Chief Medical Officer of the Board of Education, London, UK. *British Medical Journal* 1(2560), 213-215.

Bulwer, J. (1648). *Philocophus, or, The deafe and dumbe mans friend*. Humphrey Mosley, London, UK.

Bureau of Labor Statistics (2020). *Employment Projections: 2019-2029 Summary*. Office of Occupational Statistics and Employment Projections, United States Bureau of Labor Statistics, Washington, DC. Available at https://www.bls.gov/news.release/ecopro.nr0.htm. Accessed April 19, 2021.

Carabellese, C., Appollonio, I., Rozzini, R., Bianchetti, A., Frisoni, G. B., Frattola, L., and Trabucchi, M. (1993). Sensory impairment and quality of life in a community elderly population. *Journal of the American Geriatrics Society* 41, 401-407.

Centers for Disease Control and Prevention (2019). Summary of Hearing Screening Among Total Occurrent Births (2019). Centers for Disease Control and Prevention, Department of Health and Human Services, Atlanta, GA. Available at https://bit.ly/3sG2yWm Accessed January 14, 2021.

Cooper, A. P. (1801). Farther observations on the effects which take place from the destruction of the membrana tympani of the ear: An Account of an operation for the removal of a particular species of deafness. Communicated by Everard Home, Esq., Fellow Royal Society. *Philosophical Transactions* XXIII, 435-450.

Dölger, R. (1927). *Militärdienst und Gehörorgan. Die Krankheiten des Gehörorgans Dritter Teil Otitische Intrakranielle Komplikationen Gewerbekrankheiten u Akustisches Trauma Mechanisches und Psychisches Trauma · Taubstummheit · Ohr und Schule · Militärdienst und Gehörorgan · Simulation und Dissimulation Ohrenkrankheiten und Lebensversicherung.* Julius Springer, Berlin, Germany.

Du Verney, G. J. (1683). *Traite de l'organ de l'ouie; contenant la Structure, les Usages et les Maladies de toutes les parties de l' Oreille*. Chez Estienne Michallet ruë S. Jacques à l' Image S. Paul, Paris, France.

Eastwood, M. R, Corbin, S. L., Reed, M., Nobbs, H., and Kedward, H. B. (1985). Acquired hearing loss and psychiatric illness: An estimate of prevalence and co-morbidity in a geriatric setting. *British Journal of Psychiatry* 147, 552-556.

Ewing, I., and Ewing A. (1944). The ascertainment of deafness in infancy and early childhood. *Journal of Laryngology* 59, 309-333.

Feldman, H. (1979). *A History of Audiology.* Belltone Translations, Chicago, IL.

Fisch, L (1957). The importance of auditory communication. *Archive Diseases of Childhood* 32, 230-235.

Fletcher, H. (1929). The progress of hearing test in the public schools of the United States. *Transactions of the American Child Health Association* 6, 73-78

Fowler, E. P. (1947). The tests for hearing. In E. P. Fowler (Ed.), *Loose-Leaf Medicine of the Ear* 369-422A. Thomas Nelson and Sons, New York, NY.

Fowler, E, P., and Wegel, R. (1922). Presentation of a new instrument for determining the amount and character of auditory sensation. *Transactions of the American Otological Society* 16, 105-123.

Hardy, J. B. (1965). The young deaf child: Identification and management, Proceedings of a Conference, Toronto, ON, Canada, October 8-9,1964. *Acta Oto-Laryngologica (Stockholm) Supplement* 206, 34-36.

Hearing Review (2021). *A March Sales Surge? An Analysis of Seasonal Fluctuations in Hearing Aid Sales*. Available at https://www.hearingreview.com/?s=hearing+aid+sales. Accessed March 21, 2021.

Helmholtz, H. (1863). *Die Lehre den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*. F. Vieweg und Sohn, Braunschweig, Germany.

Hunter, M. F., Kimm, L., Dees, D. C., Kennedy, C. R., and Thornton A. R. D. (1994). Feasibility of otoacoustic emission detection followed by ABR as a universal neonatal screening test for hearing impairment. *British Journal of Audiology* 28, 47-51.

Itard, J. M. G. (1821). *Traité des maladies de l'oreille et de l'audiion*. Chez Méquignon-Marvis A Paris, France.

Jewett, D. L., and Williston, J. S. (1971). Auditory-evoked far fields averaged from the scalp of humans. *Brain* 94, 681-696.

Kemp, D. T. (1978). Stimulated acoustic emissions from within the human auditory system. *The Journal of the Acoustical Society of America* 64, 1386-1391.

Kennedy, C. R., Kimm, L., Dees, D. C., Evans, P. I., Hunter, M., Lenton, S., and Thornton, R. D. (1991). Otoacoustic emissions and auditory brainstem responses in the newborn. *Archives of Disease in Childhood* 66, 1124-1129.

Lam, B. L., Lee, D. J., Gomez-Marin, O., Zheng, D. D., and Caban, A. J. (2006). Concurrent visual and hearing impairment and risk of mortality: The National Health Interview Survey. *Archives of Ophthalmology* 124, 95-101.

Marchese-Ragona, R., Pendolino, A. L., Mudry, A., and Martini, A. (2019). The father of the electrical stimulation of the ear. *Otology and Neurotology* 40, 404-406.

McKenzie, D. (1920). *Diseases of the Throat, Nose and Ear*. Heinemann, London, UK.

Metselaar, M., Maat, B., Krijnen, P., Verschuure, H., Dreschler, W. A., and Feenstra, L. (2009). Self-reported disability and handicap after hearing-aid fitting and benefit of hearing aids, comparison of fitting procedures, degree of hearing loss, experience with hearing aids and uni- and bilateral fittings. *European Archives of Otorhinolaryngology* 266, 907-917.

National Institute for Occupational Safety and Health (NIOSH) (1998). *Occupational Noise Exposure Revised Criteria 1998*. Publ. No. 98-126, NIOSH Criteria for a Recommended Standard, NIOSH, United Stated Department of Health and Human Services, Cincinnati, OH.

National Institutes of Health (1993). *Early Identification of Hearing Impairment in Infants and Young Children*. National Institutes of Health Consensus Statement March 1-3, 1993. Available at https://consensus.nih.gov/1993/1993hearinginfantschildren092html.htm.

Neumann, K., Chadha, S., Tavartkiladze, G., Bu, X., and White, K. R. (2019). Newborn and infant hearing screening facing globally growing numbers of people suffering from disabling hearing loss. *International Journal of Neonatal Screening* 5, 7.

Occupational Safety and Health Administration (OSHA) (2021a). *Standard Number 1910.95 – Occupational Noise Exposure*. OSHA, United States Department of Labor, Washington, DC. Available at https://bit.ly/39vgxqp. Accessed January 10, 2021.

Occupational Safety and Health Administration (OSHA) (2021b). *Hearing Conservation*. OSHA, United States Department of Labor, Washington, DC. Available at https://bit.ly/3B3mt5m. Accessed April 18, 2021.

Palmer, C. V., Adams, S. W., Bourgeois, M., Durrant, J., and Rossi M. (1999). Reduction in caregiver-identified problem behaviors in patients with Alzheimer disease post-hearing-aid fitting. *Journal of Speech, Language, and Hearing Research* 42, 312-328.

Pirsig, W., and Stephens, D. (1994). *De historia auris et de cultura*, private press, Ghent, Belgium.

Politzer, A. (1901). *Lehrbuch der Ohrenheilkunde für praktische Ärzte und Studierende*. F. Enke, Stuttgart, Germany.

Politzer, A. (1902a). *A Text Book of the Diseases of the Ear for Students and Practitioners,* 4th ed. Lea Brothers and Co., Philadelphia, PA.

Politzer, A. (1902b). *Requirements in Regard to the Years and Hearing of Applicants for Establishment into the Army and Navy of the United States and of Great Britain: Diseases of the Ear.* Translated by M. J. Ballin and C. L. Heller. Lea Brothers and Co., Philadelphia, PA, pp. 801-812.

Politzer, A., Ballin, M. J., and Heller, C. L. (1903). *A Textbook of the Diseases of the Ear for Students and Practitioners*. Lea Brothers and Co., Philadelphia, PA.

Ramazzini, B. (1700). *De morbis artificum diatriba*. Typis Antonii Capponi, Mutinae, Modena, Italy.

Ramazzini, B. (1964). *De Morbis Artificum (Diseases of Workers).* Translated from the Latin Text of 1713 by W. C. Wight. Hafner Publishing Co., New York, NY.

Rinne, H. A. (1855). Beiträge zur Physiologie des menschlichen Ohres. *Vierteljahrschrift für die praktische Heilkunde* 44, 46:71-123.

Ruben, R. J. (2000). Redefining the survival of the fittest: communication disorders in the 21st century. *Laryngoscope* 10, 241-245.

Ruben, R. J., Knickerbocker, G. G., Sekula, J., Nager, G. T., and Bordley, J .E. (1959). Cochlear microphonics in man a preliminary report. *Laryngoscope* 69, 665-671.

Terkildsein, K., and Thomsen, K. A. (1959). The influence of pressure variations on the impedance of the human ear drum. A method for objective determination of the middle-ear pressure. *Journal of Laryngology and Otology* 73, 409-418.

Toynbee, J. (1860). *The Diseases of the Ear: Their Nature, Diagnosis and Treatment*. John Churchill, London, UK.

Weber, E. H. (1834). *De pulsus resorptione, auditu et tactu. Annotationes anatomicæ et physiologicæ*, Lipsiæ, Germany.

White, K., Vohr, B., and Behrens, T. (1993). Universal newborn hearing screening using transient evoked otoacoustic emissions. Results of the Rhode Island Hearing Assessment Project. *Seminars in Hearing* 14, 18-29.

White, K., Vohr, B., Maxon, A., Behrens, T., McPherson, M., and Mauk, G, (1994). Screening all newborns for hearing loss using transient evoked otoacoustic emissions. *International Journal of Pediatric Otorhinolaryngology* 29, 203-217.

Winslow, W. H. (1882) *The Human Ear and Its Diseases: A Practical Treatise upon the Examination, Recognition, and Treatment of Affections of the Ear and Associate Parts*. Boericke and Tafel, New York, NY.

Wolf, O. (1871). *Sprache und Ohr: akustisch-physiologische und pathologische Studien*. Friedrich Vieweg und Sohn, Braunschweig, Germany.

Wolke, C. (1802). *Nachricht von den zu Jevere durch die Galvani-Voltaische Gehörgenbekunst beglückten Taubstummen*. In der Schulzescnen Buchhalund, Oldenberg, Germany.

About the Author

Robert Ruben
rruben@montefiore.org
Department of Otorhinolaryngology – Head & Neck Surgery
Albert Einstein College of Medicine
Montefiore Medical Center
Greene Medical Arts Pavilion
3400 Bainbridge Avenue
Bronx, New York 10467, USA

Robert Ruben, a member of the Acoustical Society of America, is chairperson of the Section of History of Medicine and Public Health of the New York Academy of Medicine; distinguished professor of Otolaryngology and Pediatrics at the Albert Einstein College of Medicine, Bronx, New York; and emeritus and founding editor of the *International Journal of Pediatric Otolaryngology*. He has served in numerous leadership and administrative positions pertaining to basic science and clinical aspects of otolaryngology and is a founding member of the International Society for the History of Otorhinolaryngology.

BE SURE TO VISIT *AT* COLLECTIONS!

bit.ly/AT-Collections

See editoral on page 8 to learn how to contribute to Collections.