From Father Flanagan to Hearing Research: A History of Acoustics Research at Boys Town

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How Boys Town, an organization known for work with at-risk children, became an important contributor to hearing, speech, and language research.

Father Edward Flanagan, the actor Spencer Tracy, and the multibillionaire Warren Buffett all played a role in the creation of the Boys Town communication disorders research program. As a result, in the last 40 years, more than 300 articles published in *The Journal of the Acoustical Society of America* (*JASA*) and many articles elsewhere, have been authored or coauthored by members of the faculty and staff at the Boys Town National Research Hospital (BTNRH). How did Boys Town, an organization known for work with at-risk children, become an important contributor to hearing and speech research?

It all started with Father Flanagan (see acousticstoday.org/Flanagan), a young priest who started a program for homeless boys in Omaha, NE, in 1917. In 1921, Father Flanagan's Boys' Home moved to a farm outside Omaha that he christened Boys Town. The program became famous during the depression. Spencer Tracy, the great American actor (see acousticstoday.org/tracy), received an Academy Award (Oscar) for playing Flanagan in the 1938 MGM movie *Boys Town*, where another famous actor, Mickey Rooney (see acousticstoday.org/Rooney), played the part of a homeless boy (see youtu.be/IgReY000HHE). The success of the movie enabled the organization to expand its already extensive national fundraising efforts. Father Flanagan died of a heart attack in 1948 while investigating the need for relief efforts for children in Europe on behalf of President Harry Truman.

Fundraising continued, but the expansion of Boys Town and its programs did not. In the early 1970s, the American financier Warren Buffett was building an investment empire that would make him one of the world's richest people. When Buffet found that nonprofit foundations were required to report financial information to the US government that was then available to anyone on request, he requested information for Boys Town and was surprised by what he learned. As a result, on March 30, 1972, the *Omaha Sun*, a weekly newspaper owned by Warren Buffett, used information provided by Buffett to publish a Pulitzer Prize-winning expose of Boys Town finances showing that the organization was sending out 50 million appeal letters per year while quietly amassing an endowment of $209 million that was growing annually. The reporters showed that Boys Town had developed one of the largest direct-mail fundraising programs in the country to raise money that it did not appear to need. In less than a year, this revelation resulted in new leadership, a new board of directors, and a search for new programs to expand the mission and serve additional children.

Dr. Patrick Brookhouser, the chief otolaryngology resident at Johns Hopkins University (Baltimore, MD) in 1972, had grown up near Omaha, still had family in the area,

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and was closely following the Boys Town events. Pat's mentor, John Bordley, had hoped to develop an institute devoted to communication disorders in children in Baltimore but was unable to raise the necessary funds. Shortly after the scandal broke and with Bordley's encouragement, Brookhouser spent a weekend putting together a proposal for a Boys Town Institute for Communication Disorders in Children. In December 1972, the Boys Town Board of Directors agreed to fund the project, with $14 million for a building and an annual budget of $2.2 million. The name was changed in 1989 to the Boys Town National Research Hospital (BTNRH). To avoid confusion, that name is used for the remainder of this article.

Figure 1. *Boys Town National Research Hospital (BTNRH) in 2015.* ***Left:*** *original building.* ***Right:*** *a second building, the Lied Learning and Technology Center, was added in 2004 to provide space for outreach and continuing education functions and a preschool for deaf and hard-of-hearing children as well as clinical and research space for cochlear implant and speech-language programs.*

The First Ten Years

Brookhouser was named director of the new program at the age of 32. He had no staff or administrative experience, and the Boys Town organization had no experience in the provision of medical services, research, or obtaining federal funding. In retrospect, it is remarkable that the new venture was successful. The BTNRH succeeded, however, because it was able to recruit people for key positions who were interested in a mix of basic and clinical research, wanted to escape the administrative complexity found in universities, were attracted by the opportunity that the BTNRH afforded to build a new research-oriented institution from scratch, and were drawn to the overall mission. Many of these people were recent PhDs willing to take the risk of moving to a new institution, with many remaining at the BTNRH for their entire careers. With no history, no fixed administrative structure, no specific teaching responsibilities, and financial support from Boys Town, they were free to develop programs that maximized impact.

Brookhouser's proposal called for development of a center for the diagnosis and treatment of children with communication disorders at no cost to their families. Like all Boys Town programs, it would be nondenominational. It also included an interdisciplinary research program, with seven laboratories with an emphasis on what is now called translational research and supported by institutional funds. Most clinically oriented research programs at that time, such as the one at the Central Institute for the Deaf (St. Louis, MO), had grown out of successful clinical programs. The plan for the new center was to develop clinical and research programs in parallel with one another. The clinical programs would include otolaryngology and pediatrics, but the emphasis was on audiology, speech language pathology, learning disabilities, and clinical psychology.

While Brookhouser completed his military service, Bordley helped assemble advisory committees and develop more detailed plans.

Senior people were recruited to organize clinical programs in audiology and speech and language disorders, including Donald Worthington from his position as Director of the Army Audiology and Speech Center at Walter Reed Army Medical Center (Washington, DC; now Walter Reed National Military Medical Center, Bethesda, MD), Noel and Arlene Matkin from Northwestern University (Evanston, IL), and Betty Jane Phillips from Kent State University (Kent, OH). The first research advisory committee included Joseph Hind, an auditory physiologist at the University of Wisconsin (Madison), Merle Lawrence, an authority on speech production and founding director of the Kresge Hearing Research Institute at the University of Michigan (Ann Arbor), and Catherine Smith, a noted auditory anatomist.

Murray Sachs, a member of the Johns Hopkins faculty in biomedical engineering and otolaryngology, was instrumental in the development of early plans for the research program but decided to stay in Baltimore rather than move to Omaha as director of research at the new institution. Joe Hind then recommended one of his postdoctoral fellows, Eric Javel as interim director of research. Like Sachs, Javel was a physiologist but his undergraduate degree from Johns Hopkins may have sealed the deal. Javel then recruited the author of this article, a postdoctoral fellow working with David Green, to establish a research program in psychoacoustics.

After a three-year planning period, the initial staff of the hospital moved to Omaha in 1975 and 1976, working out of temporary quarters until a new building was completed in February 1977. Because the BTNRH was a totally new institution, the building (see **Figure 1**) was designed and construction was completed before most of the staff members who would occupy the building were recruited.

The highest priorities in 1976 were to recruit a permanent research director and to obtain additional funding for the research program. Many people contributed to the initial development of the BTNRH, but the research program owes its success to Charles Watson and support from the National Institutes of Health (NIH). Watson was recruited from the Central Institute for the Deaf during the fall of 1976 and moved to the hospital as director of research in January 1977. He was instrumental in the recruitment of additional laboratory directors, the development of initial grant applications, and, most of all, in establishing the tone of the research program, including its academic orientation and high standards for performance.

In 1976, the NIH announced a new initiative for institutions currently without NIH funds to provide three years of research start-up funds with a total budget of $300,000. They invited applications in any area of research supported by the NIH and planned to award four such grants. Watson and the other early members of the research staff submitted an application for the March 1, 1977, deadline, only a month after they had moved into the new building. It was the first application for federal funds submitted by the Boys Town organization.

The application was funded with a start date of December 1, 1977. It provided operating funds for the existing laboratories, funds for equipment, and initial operating funds for new laboratories in communication engineering, neuroanatomy, and speech/language, with support for senior salaries guaranteed by the BTNRH. Recruitment of additional staff was initiated during this period and the day that word of funding was received from the NIH, Richard Lippmann accepted the position in communication engineering and W. Bruce Warr accepted the position in neuroanatomy. Ronald Netsell later accepted the speech/language position, joined immediately by Raymond Kent.

NIH approval and support for the new research program provided validation that was critical in an organization with no prior experience in research. In addition to the funding, the positive external review of grant applications provided strong feedback to the Boys Town organization regarding the value of the proposed work. It also provided individual laboratory directors the freedom to pursue research topics of great interest to their peers on grant-review panels that might have been difficult to explain to the Boys Town Board of Directors.

Richard Lippmann and Bruce Warr arrived in 1978. Lippmann was interested in the development of new algorithms for hearing aid signal processing, whereas Warr had done seminal work to map the efferent innervation of the inner ear. Ron Netsell and Ray Kent moved from the University of Wisconsin the following year to establish a speech physiology laboratory (see **Figure 2**). By the end of 1978, Javel, Jesteadt, Watson, and Warr had all obtained NIH funding for their research programs, an excellent electronics shop and other research infrastructures had been developed, and the BTNRH had hosted a national research conference combined with a meeting of the Committee on Hearing and Bioacoustics of the National Academy of Sciences (Brookhouser and Bordley, 1980). William Kimberling also joined us that year to develop one of the first research programs in the area of the genetics of hearing loss. Kimberling went on to do pioneering work at the BTNRH on the identification of genes causing Usher syndrome, the leading cause of combined deafness and blindness in developed countries (Kimberling and Möller, 1995).

Figure 2. Left to right: *Charles Watson, Richard Lippmann, and Raymond Kent discussing the acoustics of the vocal tract, 1980.*

The initial growth phase of the research program ended in 1983, when Watson moved to Indiana University (Bloomington). By that time, there were 18 independent laboratories and important elements of the research program were in place.

Scope of the Research Program

Brookhouser's initial proposal assumed that the seven laboratories would cover a wide range of disciplines, which is evident in a long history of contributions to neurochemistry, molecular genetics, and biophysics at one extreme and education of deaf children and language development at the other. The emphasis in this review is on work in areas directly related to acoustics as evidenced by publications in *JASA*, but the existence of research efforts in these other areas certainly contributed to the success of the portions of the research program described here and to the impact of the research program as a whole.

Brookhouser himself made important contributions to academic otolaryngology, but the BTNRH was not in a position to recruit many academically oriented physicians because it lacked the caseload and residency programs found in large academic medical centers. And although the research program was heavily focused on hearing for many years, it has recently expanded into language disorders, functional magnetic resonance imaging (fMRI) studies of neurobehavioral development, and related areas.

Translational Research

Most of the laboratory directors recruited in the initial years came from basic research backgrounds and continued to pursue work in those areas at the BTNRH. At that time, NIH and National Science Foundation (NSF) grant-review panels funded more basic research than clinically oriented research and there was less interest nationally in what is now called translational research that extends laboratory work to the clinic. That was a major goal of the BTNRH, however; so in that sense, we were ahead of the times. Despite the institutional goal, it was difficult to bridge the gap between the research laboratories and the clinics, a problem confronted by many other research programs. Researchers and clinicians met to discuss interesting patients seen in the clinic, but there was little actual research collaboration. This changed in the early 1980s as a result of the recruitment of additional staff.

Turnover in the audiology clinic in 1981 resulted in recruitment of two recent graduates of the University of Iowa (Iowa City), Pat Stelmachowicz as coordinator of audiology and Michael Gorga as head of a human sensory physiology laboratory, with the responsibility for clinical evoked-potential testing as well as research. Stephen Neely joined the research program in 1982 as head of the communication engineering laboratory, the position initially held by Richard Lippmann. Neely had developed the first model of cochlear mechanics that included active elements. Donna Neff joined the research program in 1983. Mary Pat Moeller came to the BTNRH as a master's level clinician in 1978 but became involved in research in the early 1980s and later received a PhD from the University of Nebraska-Lincoln. In 1994, she became director of our speech, language, and aural habilitation programs, where she provided strong research leadership for these clinical programs. This core group of Jesteadt, Stelmachowicz, Gorga, Neely, Neff, and Moeller remained at the BTNRH for their entire research careers and along with Douglas Keefe, a late arrival in 1995, formed the backbone of the hearing research program (see **Figure 3**).

Figure 3. Left to right: *Walt Jesteadt, Mary Pat Moeller, Patrick Brookhouser, Pat Stelmachowicz, and Michael Gorga in the BTNRH lobby, 2012.*

Examples of Significant Research Contributions

The BTNRH research program has been broad from its inception and has made important contributions in many areas. One example concerns contributions to the advent of universal newborn hearing screening in the 1990s (Brookhouser, 2002). Newborn hearing screen was made possible by the development of methodology and normative data for objective measures of hearing based on auditory brainstem responses (ABRs) and otoacoustic emissions (OAEs). The initial goal of the work in Gorga's laboratory beginning in the early 1980s was to demonstrate and improve the accuracy with which the pure-tone audiogram could be predicted from the ABR, an evoked potential generated by the peripheral auditory system, used as a measure of hearing in newborns and others who were unable to be tested behaviorally. To develop normative data that could be used clinically, Gorga focused on calibration issues and the collection of large sets of data from infants and young children including infants who graduated from an intensive care nursery.

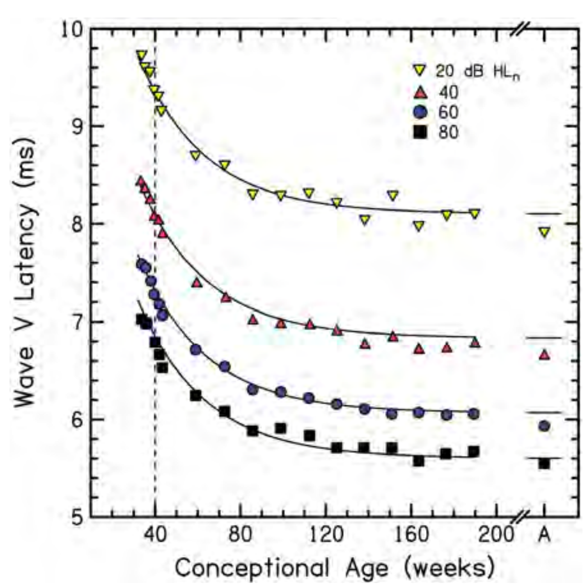
At the same time, Neely began working with Susan Norton, a BTNRH postdoctoral fellow at the time, to obtain data on click-evoked and tone burst-evoked OAEs, low-level acoustic signals recorded in the ear canal generated by the cochlea in response to acoustic stimuli (Norton and Neely, 1987). OAEs had recently been discovered by Kemp (1978) and provided Neely with a convenient source of data that could be incorporated into his models of cochlear responses. One of the major issues at that time was whether OAE-response latencies were too long to be accounted for by cochlear mechanics.

To answer the question, Neely and Gorga combined forces on a project that compared the latency of ABR and OAE responses with that of tone-burst stimuli (Neely et al., 1988). They noted that OAE responses could be modeled as having twice the latency of ABR responses, if one assumed that the ABR response consisted of a peripheral component that varied with frequency and intensity and a central component that was independent of both. It was not widely understood at the time, however, that the cochlear traveling wave moved more quickly at higher intensities, making it important to compare OAE and ABR latencies at the same level. It was also not widely accepted that cochlear latencies are longer in humans compared with other species typically used in hearing research.

The collaboration between Gorga and Neely began in earnest following an internal seminar in 1987 where Gorga described click-evoked ABR data from 1,120 infants and children ranging in age from 32 weeks gestational age to 3 years of age. After the presentation, Neely asked if he could reanalyze the data, and a few hours later, he came into Gorga's office, put two figures and an equation on his desk, and stated that the data proved that the cochleas of humans are mature at birth. The key figure is shown here in **Figure 4**, where Neely was able to fit the data for four presentation levels with an exponential equation that assumed that the effects of level and age were independent of one another. Neely argued that the latency of the central component was independent of the intensity but decreased with age, completely accounting for the effect of age in the data. The latency of the peripheral component decreased with intensity at the same rate at all ages. Gorga was stunned by the significance of this analysis because the status of the cochlea at birth was hotly debated at the time. The resulting paper by Gorga et al. (1989) was one of 74 of their joint publications in peer-reviewed journals, 48 of which appeared in *JASA*.

Research in Gorga's laboratory then shifted to collection of OAE data, specifically distortion-product otoacoustic emissions (DPOAEs), where the stimulus consisted of two closely spaced tones and the emission was recorded at the frequency of a combination tone, typically a frequency twice the lower stimulus frequency minus the higher frequency ($2f_1 - f_2$). DPOAEs had the advantage of providing frequency-specific data while allowing the separation of the stimulus from the emission in ear canal recordings. In a series of papers, Gorga, Neely, and colleagues determined optimum stimulus parameters for the generation of DPOAEs and published DPOAE data that provided a framework for interpreting DPOAEs in the clinic (Gorga et al., 1993, 1997). As part of this work,

Figure 4. *Auditory brainstem response (ABR) wave V latency as a function of age can be described by the same exponential function at all stimulus presentation levels. Wave V latency =* $4.89 + 4.46e^{-0.0318a} + 5.31e^{-0.0251i}$*, where a is conceptional age in weeks and i is the level in decibels (*HL_n*), where 0 dB* HL_n *is equivalent to a peak sound pressure of 30 dB re 20 μPa. After Gorga et al., 1989, Figure 5.*



the BTNRH participated in the planning and execution of a multicenter study to determine the accuracy of a combination of ABR and OAE measures in universal newborn hearing screening (Norton et al., 2000). The study resulted in the recommendation of the two-stage screening process, starting with OAEs and followed by an ABR in those infants who fail the OAE screening, that is used in most universal newborn hearing screening programs today.

In the course of the multicenter newborn hearing screening study, Douglas Keefe expressed an interest in moving to the BTNRH to pursue work on the clinical applications of his measures of middle ear transfer functions. Keefe had developed a system for making wideband reflectance measurements in human ears that is capable of assessing forward and reverse pressure contributions in the ear canal in response to clicks (Keefe, 1997). A pressurized version of the test resulted in a new and significantly improved version of tympanometry that provided reflectance data over a wide range of frequencies. Work at the BTNRH demonstrated that reflectance measurements were accurate in predicting conductive hearing loss in children classified as having otitis media with effusion (Keefe et al., 2012). Wideband reflectance measures were an important contribution to newborn hearing screening because fluid in the newborn middle ear accounts for a high percentage of the false positives encountered in OAE and ABR screening. In collaboration with others, Keefe demonstrated this utility in a large-scale study of well babies before their hospital discharge (Sanford et al., 2009). The potential impact of these observations in terms of health-care costs cannot be overstated.

The advent of universal newborn hearing screening in the 1990s revolutionized pediatric audiology and aural habilitation by greatly reducing the age at which hearing loss was identified. In addition to the work by Gorga, Neely, and others on the methodology for hearing screening, others at the BTNRH were involved in groundbreaking research on the treatment and consequences of hearing loss in newly identified infants and children.

Patricia Stelmachowicz and colleagues demonstrated the importance of amplification at frequencies above 4 kHz for speech and language development in infants and children with hearing loss (Stelmachowicz et al., 2001, 2004). The data are shown in **Figure 5**. At that time, results suggested that high-frequency gain would not improve and might actually degrade speech recognition in adults with hearing loss, by far

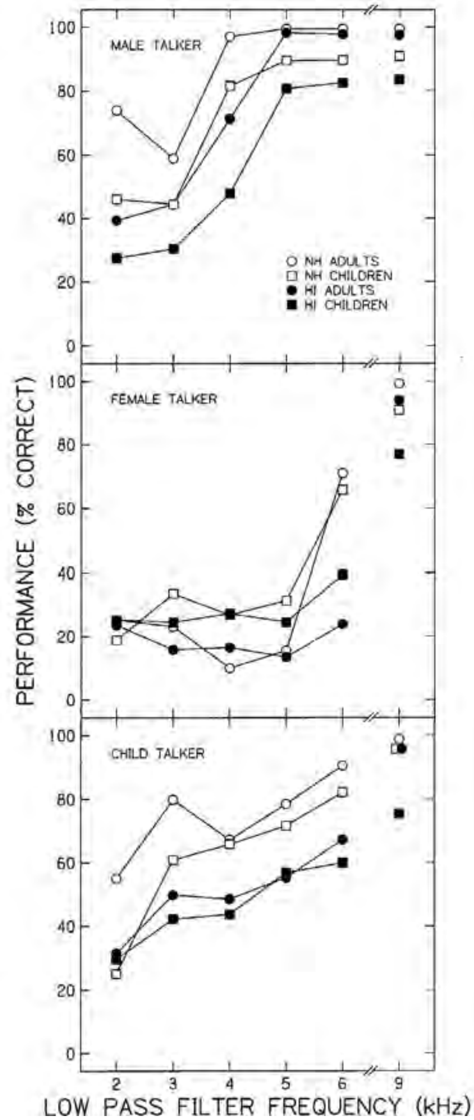


Figure 5. *Speech perception accuracy improves with bandwidth out to 9 kHz for female and child talkers. NH, normal hearing; HI, hearing impaired. From Stelmachowicz et al., 2001, Figure 3.*

the largest segment of the hearing aid market. Little thought, however, had been given to the fact that high frequencies that were not transduced by hearing aids carried information about fricatives that marked plurals in English, an important factor in language development and in speech production by children with hearing loss. Work by Stelmachowicz and her colleagues had a major impact on hearing aid design and fitting for the pediatric population.

Mary Pat Moeller took the lead in longitudinal studies exploring the consequences of infant hearing loss on a range of child and family outcomes. She codirected with J. Bruce Tomblin a multicenter study in collaboration with colleagues at the University of Iowa and the University of North Carolina at Chapel Hill. This work demonstrated the impact of early hearing aid fitting and use on linguistic and academic development over a 10-year period in a large group of children who were hard of hearing compared with normal-hearing age-mates (Moeller and Tomblin, 2015; Tomblin et al., 2015; see ochlstudy.org).

The BTNRH faculty have also made important contributions to research on cochlear implants as well as basic research on psychoacoustics and on speech perception. Work on cochlear implants was begun by Robert Shannon (Shannon, 1989) and continued by Michelle Hughes (Hughes and Stille, 2009) and Monita Chatterjee and Adam Bosen (Bosen and Chatterjee, 2016). Much of this work relied on methodology developed in the psychoacoustics literature. Examples of BTNRH contributions in that area include work by Stelmachowicz on the growth of masking in listeners with hearing loss (Stelmachowicz et al., 1987), by Neff on informational masking (Neff, 1995; Leibold and Neff, 2007), and by Huanping Dai on pitch perception (Dai, 2000). The author has worked on a number of psychoacoustics topics ranging from forward masking (Jesteadt et al., 1982) to loudness summation (Jesteadt et al., 2019). BTNRH publications on speech perception have ranged from work by Susan Nittrouer (2001) on phonetics to more recent work by Buss, Leibold, and colleagues (2017) on the effects of masking on speech perception by children.

Recent Developments

Many people contributed to the BTNRH research program over the years, but by 2010, there was concern that several members of the long-term core group would be retiring at about the same time, without obvious replacements available for key leadership positions. The BTNRH had always been most successful at recruiting people early in their careers, and many of those people had moved to positions in universities. We had not recruited an established, midlevel researcher since Keefe joined the staff in 1995. Several of our more recently recruited early-career people were not successful in obtaining external support for their research programs, and it was also unclear who would eventually replace the BTNRH founding director, Patrick Brookhouser, or how that transition would be handled.

Much of this uncertainty was resolved over the next few years. Pat Brookhouser died unexpectedly in the fall of 2011 and was replaced by our long-term hospital administrator who continued the strong institutional commitment to the research program. Monita Chatterjee moved her well-established cochlear implant research program to the BTNRH in 2012, attracted by the availability of cochlear implant patients and freedom from teaching and other university duties, the same factors that drew scientists to the BTNRH in its early years of development. In 2014, the BTNRH received NIH funding for a center of excellence in research related to perception and communication in children. The new funding provided support for several of our early-career investigators and a mechanism for recruiting and supporting additional scientists over the coming years with the goal of expanding the research program into new areas. In 2015, we were able to recruit Lori Leibold, a former BTNRH postdoctoral fellow, to return as director of the NIH-funded center as well as of our Center for Hearing Research. Her interests in auditory development (Leibold et al., 2019) made her an excellent fit for both positions. In 2017, Ryan McCreery, who had established an independent research program at the BTNRH in 2011, was appointed as director of research. McCreery in turn led the effort to recruit Karla McGregor as a successor to Mary Pat Moeller, with the goal of developing a program in developmental language disorders, with six additional positions to be filled over the next few years. In 2019, G. Christopher Stecker moved his spatial hearing research program to the BTNRH and is in the process of equipping a new anechoic chamber that will be an important core resource for the hearing research program.

Because we now have a better understanding of the peripheral auditory system than we did in the early days of the BTNRH, the emphasis in the recent expansion of the research program has shifted to work on perception in more complex auditory environments (e.g., Leibold et al., 2019) and the contributions of memory and executive function to development of speech and language. This is now one of the few programs to have NIH-funded research on both peripheral and central mechanisms, evaluating both hearing aids and cochlear implants, in both children and adults. After 48 years, the BTNRH research program in hearing, speech, and language continues to grow and to have a major impact on the diagnosis and treatment of communication disorders in children.

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References

Bosen, A. K., and Chatterjee, M. (2016). Band importance functions of listeners with cochlear implants using clinical maps. *The Journal of the Acoustical Society of America* 140, 3718-3727.

Brookhouser, P. E. (2002). The role of the Joint Committee on Infant Hearing in the development of early hearing detection and intervention programs in the USA. *Audiology Today Special Update on Infant Hearing*, 5-10.

Brookhouser, P. E., and Bordley, J. E. (1980). Childhood communication disorders: Present status and future priorities. *Annals of Otology, Rhinology & Otolaryngology* 89(5), 1-184.

Buss, E., Leibold, L. J., Porter, H., and Grose, J. H. (2017). Speech recognition in one- and two-talker maskers in school-age children and adults: Development of perceptual masking and glimpsing. *Journal of the Acoustical Society of America* 141, 2650-2660

Dai, H. (2000). On the relative influence of individual harmonics on pitch judgment. *The Journal of the Acoustical Society of America* 107, 953-959.

Gorga, M. P., Kaminski, J. R., Beauchaine, K. L., Jesteadt, W., and Neely, S. T. (1989). Auditory brainstem responses from children three months to three years of age: Normal patterns of response II. *Journal of Speech and Hearing Research* 32, 281-288.

Gorga, M. P., Neely, S. T., Bergman, B., Beauchaine, K. L., Kaminski, J. R., Peters, J., and Jesteadt, W. (1993). Otoacoustic emissions from normal-hearing and hearing-impaired subjects: Distortion product responses. *The Journal of the Acoustical Society of America* 93, 2050-2060.

Gorga, M. P., Neely, S. T., Ohlrich, B., Hoover, B., Redner, J., and Peters, J. O. (1997). From laboratory to clinic: A large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. *Ear and Hearing* 18, 440-455.

Hughes, M. L., and Stille, L. J. (2009). Psychophysical and physiological measures of electrical-field interaction in cochlear implants. *The Journal of the Acoustical Society of America* 125, 247-260.

Jesteadt, W., Bacon, S. P., and Lehman, R. (1982). Forward masking as a function of frequency, masker level, and signal delay. *The Journal of the Acoustical Society of America* 71, 950-962.

Jesteadt, W., Wróblewski, M., and High, R. (2019). Contribution of frequency bands to the loudness of broadband sounds: Tonal and noise stimuli. *The Journal of the Acoustical Society of America* 145, 3586-3594.

Keefe, D. H. (1997). Otoreflectance of the cochlea and middle ear. *The Journal of the Acoustical Society of America* 102, 2849-2859.

Keefe, D. H., Sanford, C. A., Ellison, J. C., Fitzpatrick, D. F., and Gorga, M. P. (2012). Wideband aural acoustic absorbance predicts conductive hearing loss in children. *International Journal of Audiology* 51, 880-891.

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

Kimberling, W. J., and Möeller, C. (1995). Clinical and molecular genetics of Usher syndrome. *Journal of the American Academy of Audiology* 6, 63-72.

Leibold, L. J., Buss, E., and Calandruccio, L. (2019). Too young for the cocktail party? One reason why children and cocktail parties do not mix. *Acoustics Today* 15(1), 37-43.

Moeller, M. P., and Tomblin, J. B. (2015). An introduction to the outcomes of children with hearing loss study. *Ear and Hearing* 36, 4S-13S.

Neely, S. T., Norton, S. J., Gorga, M. P., and Jesteadt, W. (1988). Latency of auditory brain-stem responses and otoacoustic emissions using tone-burst stimuli. *The Journal of the Acoustical Society of America* 83, 652-656.

Neff, D. L. (1995). Signal properties that reduce masking by simultaneous random-frequency maskers. *The Journal of the Acoustical Society of America* 98, 1909-1920.

Nittrouer, S. (2001). Challenging the notion of innate phonetic boundaries. *The Journal of the Acoustical Society of America* 110, 1598-1605.

Norton, S. J., and Neely, S. T. (1987). Tone-burst-evoked optoacoustic emissions from normal-hearing subjects. *The Journal of the Acoustical Society of America* 81, 1860-1872.

Norton, S. J., Gorga, M. P., Widen, J. E., Folsom, R. C., Sininger, Y., Cone-Wesson, B., Vohr, B. R., and Fletcher, K. A. (2000). Identification of neonatal hearing impairment: A multicenter investigation. *Ear and Hearing* 21, 348-356.

Sanford, C. A., Keefe, D. H., Liu, Y.-W., Fitzpatrick, D., McCreery, R. W., Lewis, D. E., and Gorga, M. P. (2009). Sound-conduction effects on distortion-product otoacoustic emission screening outcomes in newborn infants: Test performance of wideband acoustic transfer functions and 1-kHz tympanometry. *Ear and Hearing* 30, 635-652.

Shannon, R. V. (1989). Detection of gaps in sinusoids and pulse trains by patients with cochlear implants. *The Journal of the Acoustical Society of America* 85, 2587-2592.

Stelmachowicz, P. G., Lewis, D. E., Larson, L. L., and Jesteadt, W. (1987). Growth of masking as a measure of response growth in hearing-impaired listeners. *The Journal of the Acoustical Society of America* 81, 1881-1887.

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., and Lewis, D. E. (2001). Effect of stimulus bandwidth on the perception of /s/ in normal- and hearing-impaired children and adults. *The Journal of the Acoustical Society of America* 110, 2183-2190.

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., Lewis, D. E., and Moeller, M. P. (2004). The importance of high-frequency audibility in the speech and language development of children with hearing loss. *Archives of Otolaryngology-Head & Neck Surgery* 130, 556-562.

Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., and Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and Hearing* 36, 76S-91S.

BioSketch

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