spectrum
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NHCA's 44th Annual Conference February 20-22, 2020 - Update

by Amy Blank
NHCA President

It's crystal clear, we're here to hear! Join your colleagues in hearing conservation at the NHCA's 44th annual conference in Destin, Florida, February 20-22, 2020.

As always, the NHCA conference highlights the latest in hearing conservation. Workshops will be offered so you can brush up on skills and learn something new. Vendors will be available to demonstrate the latest technological advances in hearing conservation.

We are pleased to introduce our keynote speaker, Jennifer Deal, Ph.D., from Johns Hopkins University. Dr. Deal is an epidemiologist and gerontologist with expertise in hearing loss and cognitive aging. She will discuss research that has demonstrated the broad implications of hearing loss for the health and functioning of older adults, particularly with respect to cognitive functioning, brain aging, and dementia and how this research informs health policy related to hearing loss. We are also pleased to introduce our Luncheon speaker, Dallas Taylor, the host of Twenty Thousand Hertz, the largest podcast in the world about sound. Mr. Taylor will take us on a journey of The Fifth Sense and explore how sound is the next frontier in wellness and luxury.

The Friday Night Event will be held at Jimmy Buffett's Margaritaville, at Harborwalk Village, in Destin, Florida, from 6-9 PM. Bus transportation will be provided, along with a buffet dinner including two drink tickets. A scavenger hunt is being planned after the dinner for those who want to spend more time in the Harborwalk area.

Stay updated to learn more about the conference, registration, the Friday Night Event, hotel reservations and more, by visiting www.nhca.civicaconferences.com and watch for updates in your email and on social media.

NHCA's 45th Annual Conference (February 11-13, 2021)

Never too early to plan for the next NHCA conference! Mark your calendars to be part of NHCA's 45th annual conference "It's Quiet Up hEAR" in Albuquerque, New Mexico, February 11-13, 2021.

in this issue

NHCA
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Spectrum is available without charge to NHCA members in all categories. Anyone interested in publishing in *Spectrum* should contact Kim Gill at the NHCA office.

The mission of the National Hearing Conservation Association is to prevent hearing loss due to noise and other environmental factors in all sectors of society.

NHCA

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presidential pEARspective

Are You Ready for Some Football?

by Amy Blank
NHCA President

I know I am! I recently attended the United States Naval Academy verses Air Force Academy football game on a beautiful Saturday afternoon. It was a great game – the crowd was fired up as the two teams fought hard in this classic rivalry. The sold-out Navy crowd was encouraged to cheer and "get loud" anytime the Air Force was on the verge of a key offensive play. As an audiologist the marquis messaging cut to my core (see examples below). Of course I whipped out my NIOSH made-for-iPhone sound level meter app and registered an instantaneous measured level of 99 dBA! These type of exposures are everywhere – hockey games, concerts, car races, basketball games, even church! What is a conscientious hearing conservationist and NHCA member to do?

Did you know October is National Protect Your Hearing Month? The world around us is a noisy place, and often we are encouraged to "turn it up" or "cheer louder". As local, regional, national or even international hearing experts, I would recommend getting out there and spreading the hearing conservation word! Hearing loss due to noise can be prevented! But where to start? What about resources?

The National Institutes of Health (NIH) National Institute on Deafness and Other Communication Disorders (NIDCD) is a valuable resource for educational resources and ways to advocate for hearing loss prevention. Through the "It's a Noisy Planet Protect Their Hearing" website one can see hearing loss prevention tips for parents, kids and preteens, and educators. Other resources include the Hearing Center of Excellence (HCE), the Centers for Disease Control and Prevention (CDC), the American Academy of Audiology (AAA) and the American Speech-Language-Hearing Associations (ASHA) Special Interest Group (SIG) 8 Audiology and Public Health. Many of these sites offer free downloadable pamphlets and posters as well as a variety of educational ideas and tips.

Online social media is doing a great job of raising awareness this month. October is also National Audiology Awareness Month and various social media sites are posting about the profession of audiology. In addition to our October festivities, Better Hearing & Speech Month (BSHM) is in May and the World Health Organization (WHO) sponsors World Hearing Day each year on March 3rd to raise awareness on how to prevent deafness and hearing loss and promote ear and hearing care across the world. Digital tool kits for planning events for 3/3 including posters, banners, infographics and presentations based on the selected theme. The theme for 2020 has not been announced, but more information on World Hearing Day and previous years' themes can be found at https://www.who.int/pbd/deafness/world-hearing-day/en/.

Back to college football. I recently saw this great poster sponsored by the Student Audiology Association at the University of Florida. Audiology students passed out hearing protection before the football game bringing awareness to spectators about the importance of protecting their hearing. I urge each of you to consider what you can do within your community to support hearing loss prevention. Visit schools for career day, talk to the Boy or Girl Scouts, participate in health fairs or distribute hearing protection or flyers at loud sporting/recreational events. Be an advocate in your community!

By the way, Navy won the game in a nail biting finish! Fear the Goat!

Photo used with permission by Alexandra White.

2019 NHCA Media Award Nominations

by Theresa Schulz
NHCA President-Elect

NHCA Call for Awards Nominations:

Awards from our peers are a meaningful way to recognize the amazing work that NHCAers do. Please read through the following information and consider appropriate recognitions.

MEDIA AWARD

The Media Award was established to recognize the efforts of writers and/or producers of news features that serve to heighten public awareness of the hazards of noise. The award is also available to NHCA members who take the time and effort to bring hearing conservation related issues into public light. Nominations may be from non-NHCA members and NHCA members are encouraged to nominate themselves.

HOW TO NOMINATE SOMEONE:

Please see the NHCA website Awards page for lists of previous awardees. If you wish to nominate someone, please contact a member of the NHCA Nominations Task Force:

- Theresa Schulz ihearU2@earthlink.net 724-554-4110
- Bob Ghent Robert.Ghent@Honeywell.com
- Dee Hightower highdee215@gmail.com
- Teah Johnson teah.johnson1@gmail.com
- Theresa Small TSmall@AssociatesinAudiology.com

NHCA's Social Media Strategy and Webinar News

by Kathy Gates
NHCA Director of Marketing and Public Relations

A new Social Media Strategy was developed for inclusion in the NHCA Policy and Procedure Manual. The primary focus of this strategy is to use social platforms to build and cultivate relationships with our members, sponsors, and the public. Activity on social networks provides insight into the interests and needs of our members. Current social media postings have focused on encouraging submission of papers and promoting NHCA's annual conference to ensure maximum participation of members and to increase the awareness of the NHCA conference among professionals external to NHCA.

The NHCA social media strategy will encourage the exchange of information among NHCA members and serve to disseminate information to other professionals to increase their awareness of NHCA and, possibly, increase future NHCA membership. The NHCA social media platforms will also provide education and motivate members to post and discuss topics related to research in noise and hearing loss prevention.

The NHCA and the Council for Accreditation in Occupational Hearing Conservation (CAOHC) held teleconference meetings to discuss plans for a new Webinar series. Potential topics for 2020 include: 1) hearing loss prevention beyond the industrial setting, 2) work relatedness, and 3) hearing loss prevention - taking it to the next level. The Webinar series is tentatively scheduled to begin in the spring of 2020. We will advertise and promote the 2020 Webinar series through our NHCA social media platforms.

NHCA Invited to Present at AAA 2020

by Dick Danielson and Theresa Schulz
AAA Liaison to NHCA and NHCA President-Elect

NHCA has once again been invited to present at the annual American Academy of Audiology Conference (April 1-4, 2020, New Orleans, Louisiana). Dick Danielson and Theresa Schulz will teach a Learning Lab entitled "How Can Clinical Audiologists Apply Contemporary Hearing Loss Prevention Evidence and Standards?"

Clinical audiologists have unique opportunities to influence their patients' attitudes and behavior about preventing noise-related hearing loss. Such advocacy calls for awareness, and application, of new and unique evidence-based advances in the prevention of hearing loss. However, these developments are frequently not published in journals traditionally read by clinicians. This session will review and summarize recent reports from multiple publications and standards pertaining to the risks, and prevention, of hearing loss caused by occupational and non-occupational noise.

If you have answers to the title question above (input on new developments, news, hot topics) for Dick and Theresa to share with our AAA colleagues, contact Dick at richard.w.danielson@nasa.gov.

Students' Corner

Maribiliz Irizarry-Torres

by Tina Campbell
NHCA Student Delegate

Maribiliz Irizarry-Torres is a fourth-year Doctor of Audiology student from the University of Puerto Rico. Her interest in hearing conservation started after taking the "Occupational and Environmental Hearing Conservation" where she learned the impact of noise on hearing health and the regulations in place to prevent noise-induced hearing loss.

In the summer of 2018, Maribiliz participated in the National Aeronautics and Space Administration (NASA) internship at Johnson Space Center in Houston, TX. Her work involved collaboration with the Acoustics Office which is responsible for ensuring the safety of acoustic environments on space vehicles. During her time in NASA, she worked with acoustic engineers obtaining acoustic measurements and making recommendations to comply with specific Noise Criterion. This experience opened her perspective on the importance and need for having a multidisciplinary approach in promoting successful hearing conservation programs.

In addition, as president of the Student Academy of Audiology Chapter of Puerto Rico (2018-2019), Maribiliz worked on several initiatives which were intended to raise awareness about noise-induced hearing loss. One of these was leading a virtual campaign of occupational noise exposure awareness through social media. This campaign helped to raise awareness about noise exposure in the workplace and methods to prevent adverse consequences. Maribiliz has also participated in multiple hearing health workshops and initiatives for children, public health graduate students, firearm users, and others in the community.

Maribiliz has been a student member of NHCA since the summer of 2018. She is excited to attend her first NHCA conference this coming February in Florida!

NHCA Scholarship Foundation Board: Update

by James Jerome
NHCA Scholarship Foundation Board President

Results of Student Conference/Research Awards

Early November, 2019, we selected five Student Conference Award and two Student Research Award recipients. Details about the recipients will be published in the upcoming Spectrum Supplement.

New Board Officers

The call for new officers to replace those whose terms will expire in February, 2020, has been extremely positive. Within one week of the announcement, we were able to fill three of the four positions posted.

Lynnette Bardolf has volunteered to be the first President-Elect on the Board.

Susan Cooper has volunteered to replace Michele Alexander as Secretary.

Brandy Hollins has volunteered to replace Tess Zacardi as Student Delegate. Brandy is currently attending the University of Pittsburgh.

Director position remains open. The Director will serve for a three year term. The Director will provide input on Board matters and may be asked to take on additional duties at the discretion of the President. If anyone is interested, please contact me (James Jerome wph-mw@sbcglobal.net).

Member Spotlight

Greg Flamme

by Elizabeth A. Matherson
NHCA Member Delegate

It is our privilege to highlight another one of NHCA's many dedicated members, each of whom has contributed to the field of hearing conservation in their own way. This Spotlight's contributor is Dr. Gregory (Greg) Flamme. Greg has been a professor and hearing loss researcher for over twenty years, and a member of NHCA since 2002. His accomplishments are long, but include key contributions to the National Health and Nutrition Examination Survey (NHANES) audiometric data collection, and the Early Childhood Longitudinal Study – Kindergarten (ECLS-K), which among other things, collects and studies hearing information for school-aged children.

The second picture depicts Greg involved in a research study of middle ear muscle contractions (I have been assured that despite the look of the helmet, no brain tissue was compromised). Most recently, Greg led the efforts to develop updated age correction tables for the Occupational Safety and Health Administration (OSHA) noise exposure regulations.

He also received the NHCA Golden Lobe award in 2004, 2005 and 2006. Greg kindly took time away from his list of projects to answer a few questions for us.

What brought you into the field of Audiology and where you are now?

I was a farm kid growing up, so I knew plenty of people with noise-induced hearing loss and had more than my share of personal experience with the exposures that likely produced those losses. During my junior year in college, I started working with my girlfriend's father, who was a hearing aid dispenser serving rural Nebraska. My interest in that work outlasted my interest in the girlfriend, and I ultimately decided to change my career aspirations from organizational sociology to helping people with hearing trouble. I'd planned to continue working on hearing aid fitting procedures and assessing outcomes, but ended up swerving in the direction of the systematic study of hearing loss prevention when I had some opportunities to work with the issues of hearing impairment in rural Iowa during my postdoctoral work. A couple of faculty positions, research grants, publications, and presentations later, I had an opportunity to work with Dr. Mark Stephenson, who wanted to start up a small research consulting operation that would let me work with some of my favorite people. Who could ask for more?

Who was the most influential person(s) in your career?

Without doubt, Dr. Robyn Cox, who was my mentor during my Master's and Ph.D. programs and I had the pleasure of working in her lab at The University of Memphis. She taught me so much more than facts and research findings. She taught me how to think, write, and be careful. I'll always treasure the memory of her telling me that she would support my application to a Ph.D. program if I felt inclined to submit one – after all, I was just hoping to survive the M.A. program!

What do you think is the most important challenge facing hearing conservation?

There are so many to choose from: a widely-shared sense of fatalism and futility of attempts to prevent hearing loss; a systematic undervaluation of the importance of excellent hearing; the failure to realize that nobody gets to have one set of ears they use at work and another set for the other exposures in their daily lives; the excessive reliance of regulations and professional bodies on provisional solutions developed half a century ago.

What can be done to address this?

We have our work cut out for us. The sense of fatalism and futility might dissipate as it becomes clearer that many of the changes in hearing with age represent exposures more than biological aging, per se. As for the importance of hearing, we started out believing that there were no meaningful consequences of a hearing loss that didn't reduce the recognition of two-syllable words in quiet. I believe we are nearing the end of a 40-year pause in progress toward regulatory and professional bodies recognizing that hearing involves so much more than speech under simple and contrived measurement conditions. We need to make it clear that, unlike many other occupational exposures, noise exposure is not limited to the workplace, which implies that exposure limits need to account for typical noise exposures in daily life. Finally, the provisional solutions to exposure limits that were developed 50 years ago need to be reconsidered in the light of what we know now and replaced with approaches that have been painstakingly evaluated by multiple independent methods and investigators. In other areas of healthcare, these things would take a few years, but we need to brace for a longer effort, given the size of the work relative to the workforce.

Of what accomplishment are you most proud, professionally?

I'm most proud of the network of collaborators surrounding me, covering lots of disciplines, academic institutions, and parts of the U.S. Government and military. I am honored that they pick up the phone when I call, because they know that the conversation might not stop for years. I would be remiss to not mention the work done by the Rudyard Group, which was named for the town in Michigan nearest Dr. Mike Stewart's hunting camp. During the last 10 years, and without sponsor funding, our merry group of volunteers has been working to tackle the problems of measuring and interpreting civilian firearm noise and the things we can do to manage it.

Of what accomplishment are you most proud, personally?

I'm proud to have earned the title "husband" to my wonderful and amazing wife, and to have accompanied my daughter on her journey from toddler to young adult.

When you aren't preventing hearing loss, what do you do for fun?

Explore the area, including hiking [Greg & Family are new to Portland, OR], spend time with family, including Conan and Angus [Labradoodles with Celtic heritage], and cook new and meticulously-planned meals.

Lightning round:

Best place you have ever traveled: Nara, Japan

Place you want to visit the most: Australia

Favorite color: blue

Favorite animal: humans (dogs are a close second)

Favorite food: too many to count

Favorite book: Hitchhiker's Guide to the Galaxy

Favorite movie: any movie that intrudes on my awareness for days or weeks afterward

Favorite sound: rain in the forest

Commercial Member Spotlight

Renée Lefrançois

Director of Audiology, SHOEBOX Ltd.

by Heather Malyuk
NHCA Commercial Delegate

One of the things I am most grateful for is my choice of Audiology as a profession. I have always had an interest in helping others, health care, and communication - which Audiology sums up beautifully.

These interests stemmed in large part from the fact that in the 1940s, my maternal aunt was born profoundly deaf after my grandmother contracted German Measles during her pregnancy. My mother's family was living on the Isle of Man at the time, a British Crown dependency in the Irish Sea. There were very little services at that time in the UK for deaf individuals who wanted to speak - and after 8 years of applications to various countries, my mother's family was finally able to immigrate to Canada in 1957. Unfortunately, my aunt's deafness was a major reason for the delay.

Although I truly enjoyed my occupational health courses during my audiology training, it wasn't until I had been practicing for 15 years that I was able to do a deeper dive into the intricacies of this unique clinical specialty.

As the Director of Audiology for SHOEBOX Audiometry, a mobile audiometry solution, more and more of our systems were being used in the occupational health sector starting from 2015 to present day. This in turn led me to research current requirements for audiometric testing, ambient noise monitoring, and professional results review at both the national and state levels.

Obtaining my Professional Supervisor Certification from CAOHC really helped bring all of this newfound education together and led to me being able to provide well-versed feedback to our software development team to help optimize our products to best serve other professionals and organizations across the country.

The vast array of valuable NHCA resources have been invaluable to my team in setting up proper parameters for baseline resetting and in addressing work-relateness of shifts in hearing. In learning from our customers, our Audiological Service Offering now includes various roles and functions from remote review services, to test protocol consultation, to overall program supervision.

It's been an exciting ride these past 4 years and I sincerely look forward to continuing the journey!

In Memoriam

Robert A. Dobie, M.D.

July 26, 1945 – September 4, 2019

by Elliott H. Berger, Susan Cooper, and Bill Clark
Friends and Collaborators

Long-time NHCA member and pioneer of hearing loss prevention Robert A. Dobie, M.D., passed away on Wednesday, September 4, 2019, in San Antonio, Texas. He was 74.

Bob grew up all over America as the son of U.S. Naval Officer, Rear Admiral E.W. Dobie, Jr. and Geraldine Frances Bonnington Dobie. Bob received his undergraduate and MD degrees from, and completed a surgical residency at, Stanford University. He was a National Merit and Phi Beta Kappa scholar, and also served as the president of his medical school class. Consistent with his childhood experiences, his academic and clinical careers were similarly diverse, both institutionally and geographically. Bob completed research and clinical fellowships in auditory physiology and neurotology with Charles I. Berlin at the Kresge Hearing Research Laboratory of the South and Professor Ugo Fisch at University Hospital, Zurich. He joined the Department of Otolaryngology-Head and Neck Surgery at the University of Washington in 1975, rapidly rising to full professor. He was a founder and the initial Director of the Virginia Merrill Bloedel Hearing Research Center there from 1988-1990.

In 1990, Bob was appointed Professor and Chairman of the Department of Otolaryngology-Head and Neck Surgery (OHNS) at the University of Texas Health Science Center, San Antonio, and he made this his academic base for the remainder of his career. He also served as the Director of Extramural Research at the National Institute on Deafness and Other Communication Disorders (NIDCD), part of the National Institutes of Health (NIH), from 1999-2002. After completing his service to the NIDCD, Bob accepted an appointment as Clinical Professor of OHNS at the University of California, Davis. In 2008, Bob returned to San Antonio and the University of Texas.

Bob's impact on research and clinical practice are difficult to overstate. In particular, his work and service on regulatory committees related to the effects of noise exposure and aging on hearing in the population led the field, and provided valuable insights for the National Institute of Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the International Standards Organization (ISO) and the World Health Organization (WHO). His papers on hearing levels of American adults have redefined the roles of aging and noise exposure on age-related hearing loss, and related national and international standards have been revised to incorporate these findings. Similarly, his work on the global burden of hearing loss and the efficacy of hearing conservation programs and standards are destined to influence our efforts to conserve the hearing of individuals as they work, play and age. These contributions will have lasting effects around the world.

Bob Dobie was a valued colleague and personal friend to many at NHCA, some for nearly 40 years. His commitment to the mission and people of NHCA is reflected in his active participation, regular attendance at the NHCA Conference, and thoughtful and insightful contributions in the form of presentations, participation in panel debates, and articles for the Spectrum. He served as an NHCA council member and task force participant, and on the council of the NHCA Scholarship Foundation. Bob received NHCA's Outstanding Hearing Conservationist Award in 2005 and Lifetime Achievement Award in 2017. He also brought his talent for applying science and pragmatism to the practice of hearing conservation by serving 10 years on the Council for Accreditation in Occupational Hearing Conservation (CAOHC). He served as an officer, a committee chair, a contributor to the CAOHC manual and was featured in the first video series for OHC courses. Bob was instrumental in the development of policies and procedures that have guided CAOHC into the leadership position it enjoys today.

Bob served as president of the Association for Research in Otolaryngology in 1992, and received both

a Presidential Citation from the Triological Society and a Distinguished Service Award from the American Academy of Otolaryngology-Head & Neck Surgery. In 2017, he was awarded the Carhart Memorial Award by the American Auditory Society. Along with his service on the editorial boards of well-respected clinical and hearing-research journals, he authored over 200 scientific publications, including a seminal book on the medical-legal evaluation of hearing loss. Among his many honors and awards, he particularly valued the Driftwood Award for outstanding teaching and mentoring skills, which he received five times from the surgical residents at the University of Washington.

Bob is survived by his wife of 47 years, Christine, daughters, Pamela Dobie Key and Monica Dobie Daly, son, William James Dobie, and numerous grandchildren. Bob will be remembered by his colleagues and friends for his unwavering integrity, well-honed wit, incisive reasoning, outstanding and compassionate service as a physician and surgeon, passionate teaching, insightful science, and being a dedicated teammate. Those who wish to honor Bob may make contributions to St. Vincent de Paul or Haven for Hope at https://svdpsa.org/donate or https://www.havenforhope.org/donate.

In closing it is apropos to report that the NHCA and the entire professional community will continue to directly benefit from Bob's work, as his family as kindly agreed to allow us to move key portions of his personal website to our NHCA website. You can find his annotated references and hearing loss calculators by going to the Resources pull-down menu and selecting Robert Dobie Memorial Library.

Selected Recent Contributions

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Custom Earplugs: Fabrication Methods and Effects on Real-Ear Attenuation at Threshold

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Introduction

Hearing protectors are often worn to reduce the risk of hearing injuries when exposed to hazardous noise. Depending on many factors, from the environment to individual preferences, a particular hearing protection device (HPD) may be needed or preferred. However, HPDs are only effective if they fit the individual well enough to reduce hazardous noise entering the auditory system to safe levels and, of course, if the individual chooses to wear them correctly while exposed to the noise. Due to the variance in anatomy between persons, one-size-fits all approach to HPDs generally does not work. As such, if a commercial off the shelf (COTS) product does not provide an adequate fit even after a number of options have been assessed, HPDs can also be tailor-made to fit the individual, commonly referred to as custom earplugs or custom-molded HPDs. Thus, custom earplugs, in theory, should "perfectly" fit the intended individual to block hazardous noise while also accommodating their specific anatomy comfortably.

There are other potential advantages of custom earplugs even for individuals that could otherwise fit a COTS HPD. Some advantages have been shown to include a more comfortable fit for longer durations (Marshall, Weathersby, McCluskey, & Huebner, 2016), a relatively consistent level of protection between fittings (Du, Homma, & Saunders, 2008) which appears to be less variable than other types of non-custom earplugs (Tufts, Jahn, & Byram, 2013), and potentially lower long term costs (Marshall et al., 2016). While custom HPDs may have some potential advantages to non-custom HPDs, not all custom earplugs are made equally. In fact, there are several ways to produce a custom earplug, which may vary by hearing professionals and earplug manufacturers.

Traditionally, custom earplugs are made using a formable material, such as silicone, which is injected into the earcanal and allowed to solidify, thereby creating a physical ear impression once removed. The physical impressions are then shipped to an earplug manufacture and either cast to create a negative mold of the ear or scanned by an ear-impression scanner to create a digital model of the physical impression. The earplug manufacturer then modifies the ear impressions (physically or digitally) to create custom earplugs, which are specific to the size and shape of the individual's ears. It is also worth noting that producing a custom earplug using a physical impression may result in iatrogenic injuries. While rare, such injuries can have severe consequences for the individual, including temporary or permanent hearing loss, tympanic membrane rupture, or middle ear damage/destruction (Wynne, Kahn, Abel, & Allen, 2000).

Custom earpieces may also be made using new technologies in optical ear scanning that provide a way to create them without making physical ear impressions thus avoiding the consequent risk of iatrogenic injury. Three companies have developed digital ear scanning technologies to create 3D models of the ear and earcanal. The digital 3D models can then be modified with computer-aided design (CAD) software to create custom earpieces and HPDs.

Digitizing the process to capture earcanal geometries for the production of custom earpieces has potential to create efficiencies while also reducing some of the discomfort and risk of injuries compared to traditional fabrication processes. To compare the performance of custom earplugs made by traditional methods and optical ear scanning technologies, an evaluation was conducted. Custom earplugs were made by traditional methods using physical ear impressions and digital scans of physical ear impressions, and three different direct digital ear-scanning methods. The real-ear attenuation of the custom earplugs made from each method was evaluated using a standard test methodology. An additional measure, comfort index, was evaluated by questionnaire.

Methods

Sound attenuation testing was conducted at the U.S. Army Aeromedical Research Laboratory (USAARL) in accordance with ANSI/ASA S12.6-2016 American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors, Method A: Trained-subject fit (ANSI, 2016). USAARL acoustical testing facilities meet all of the real-ear attenuation at threshold (REAT) specifications outlined in the ANSI/ASA S12.6 standard and has recently been granted accreditation by the National Voluntary Laboratory Accreditation Program of the National Bureau of Standards and Technology.

Twenty-four volunteer subjects (14 male, 10 female) were recruited for participation in the evaluation. All volunteers satisfied the subject requirements specified by ANSI/ASA S12.6. Three subjects were not able to participate in the study due to ear anatomy or excessive cerumen preventing ear impressions to be made. One subject was unable to return for testing. Twenty subjects (11 male, 9 female) completed the study.

Procedure

Each subject visited the laboratory on three separate occasions. On the first visit, subjects were given an informed-consent document to review and sign if they agreed to participate in the research study. After the informed consent document was signed, an otoscopic examination was performed. Subsequently, digital ear scans and physical ear impressions were obtained. Six pairs of custom earplugs were made for each subject, each from a different fabrication method. One pair was made from each of the three digital ear scanners evaluated, (AURA™ 3D ear scanning system by Lantos™ Technologies, 3Shape PHOENIX™ Scanner by 3Shape A/S, and eFit® scanner by United Sciences), one pair from physical ear impressions, one pair from digital scans of the physical impressions using a 3Shape A/S H600 scanner, and one pair was printed for each subject from one of the scanning methods previously mentioned, with the subjects divided into four groups of five subjects, each group being assigned pairs from one of the four systems.

To produce the earplugs, all eFit® scans, 3Shape scans, physical earmold impressions, and physical ear impression scans were sent to Westone® Laboratories (Colorado Springs, CO) for fabrication (custom earplug model AXHPK). Lantos scans were sent to Lantos Technologies for the production of custom earplugs from that system. Custom 3D-printed earplugs were also produced at USAARL from the various scanning methods as mentioned above, using an EnvionTEC Perfactory®µicro 3D printer with biocompatible materials. It should be noted that 3D printing was done as a proof-of-concept. Therefore, 20 pairs of custom earplugs were not printed from each scanning method due to additional cost and time that would have been required, which was not conducive to the study timeline or budget. Thus, a total of 20 pairs of custom earplugs were 3D printed (5 pairs from each of the 4 scanning methods).

After custom earplugs were fabricated, subjects returned to complete REAT testing and subjective questionnaires on comfort. Three custom earplugs were evaluated on each of the second and third visits. The order of the REAT tests was counterbalanced between subjects so that the first three earplugs evaluated by the first half of the subjects were evaluated last by the second half of the subjects.

Immediately after completing attenuation testing for each custom earplug, subjects completed a questionnaire on the perceived comfort while the hearing protector remained donned. The original comfort index was developed by Casali, Lam, and Epps (1987) and modified by Byrne, Davis, Shaw, Specht, and Holland (2011). The modified version described by Byrne et al. (2011) was used in the present study. The questionnaire consisted of 14 word pairs describing how the earplug felt to the individual. The word pairs were separated on a five-point scale with the word most associated with comfort representing a score of 1 and the word most associated with discomfort representing a 5. By summing the total points for the 14 word pairs, the comfort index ranged from 14 (most comfortable) to 70 (least comfortable).

Results

The mean attenuation results are shown in Figure 1, with the physical impression method showing the highest attenuation. Analysis of variance (ANOVA) with repeated measures on two factors (earplug fabrication method and octave-band center frequency) showed statistically significant differences between custom earplugs made from the different fabrication methods $F(30, 684) = 3.04$, $p < 0.001$. Post-hoc analysis using the Duncan multiple range test indicated statistically significant differences for each earplug fabrication method compared to the standard physical impression method at all test frequencies except for one method, which showed statistically significant differences at all but one frequency (Lantos at 2000 Hz). Furthermore, within the other five groups of fabrication methods there were no statistically significant differences between them at any test frequency.

The comfort scores are shown graphically in Figure 2. Lower scores represent more comfort, with eFit® earplugs showing the lowest score (i.e., highest comfort) on average and earplugs made from physical impression showing the highest score (i.e., least comfort) on average. ANOVA indicated statistically significant differences between the comfort scores of custom earplugs $F(5, 114) = 4.13$, $p = .001739$. Tukey HSD post-hoc analysis revealed statistically significant differences for earplugs made from physical impressions compared to 3Shape, Lantos, and eFit fabrication methods $p < 0.05$. There were no statistically significant differences between comfort scores of earplugs made from physical impressions compared to earplugs made from scanned impressions or 3D printed methods. There were no statistically significant differences between any other comfort scores.

Discussion

The results of this study indicate custom earplugs made from physical ear impressions were, on average, significantly higher attenuating than earplugs made from all other fabrication methods. The results also indicate perceived comfort of custom earplugs made from physical impressions was the lowest of all the fabrication methods evaluated in this study. This result is not surprising since other studies have indicated an inverse relationship between comfort and attenuation (Byrne et al., 2011).

All earplugs, excluding those made from physical impressions, were not significantly different from each other in terms of attenuation and comfort. While earplugs made by eFit® scans had the best mean comfort index (29), they were slightly less attenuating on average than earplugs made by Lantos, scanned impression, and physical impression methods. Thus, as attenuation decreased slightly, comfort slightly increased on average for these sets of earplugs. These differences were not significantly different but there appears to be a general inverse relationship between attenuation and perceived comfort for custom earplugs, similar to other types of earplugs.

While custom earplugs made from physical impressions showed the highest average attenuation, not all custom earplugs are made equally. The process to produce a custom earplug depends on many factors including the skill and technique of the person making the impressions as well as the manufacturing process. The same is likely true for

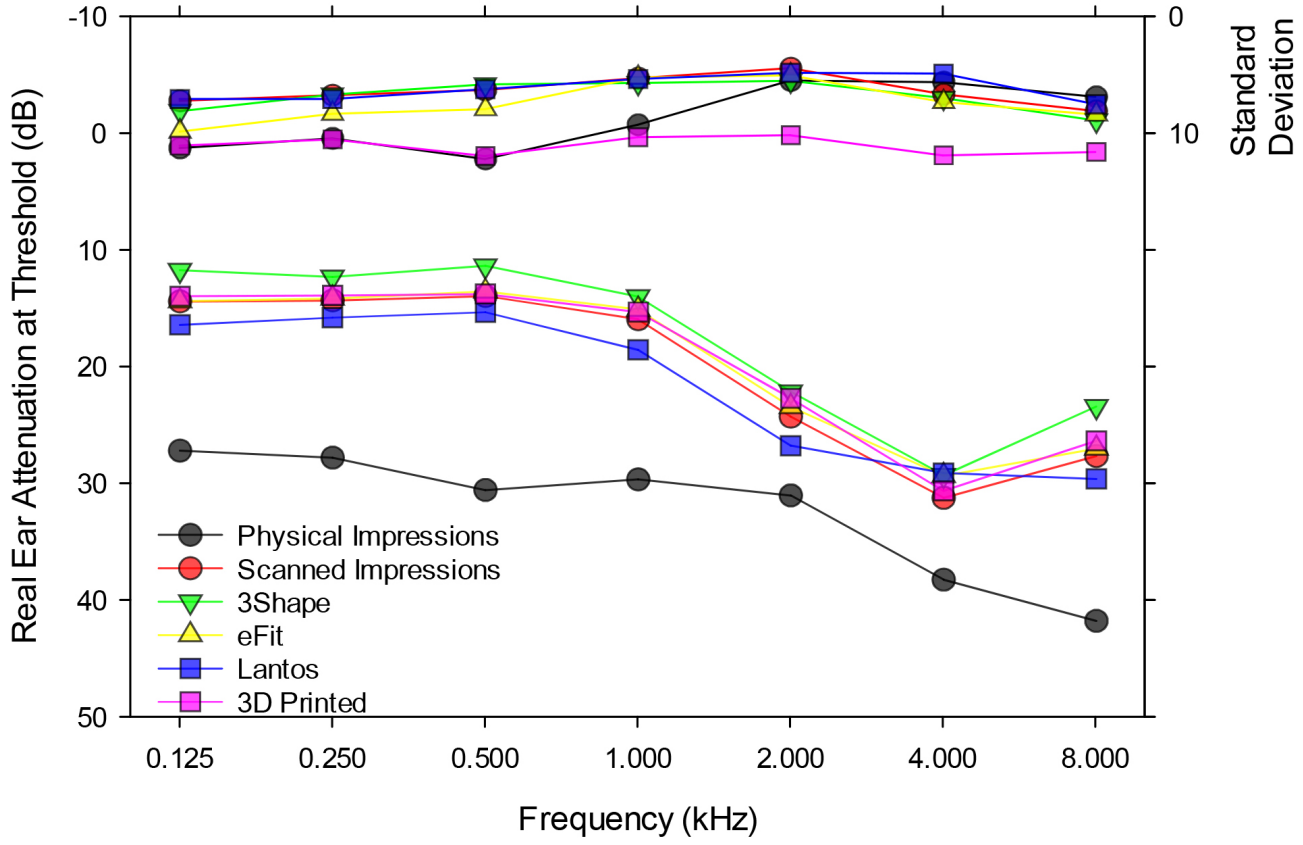

Figure 1. Mean real-ear attenuation at threshold (lower 6 curves) with values read from left axis, and associated standard deviations (upper 6 curves) with values read from the right axis.

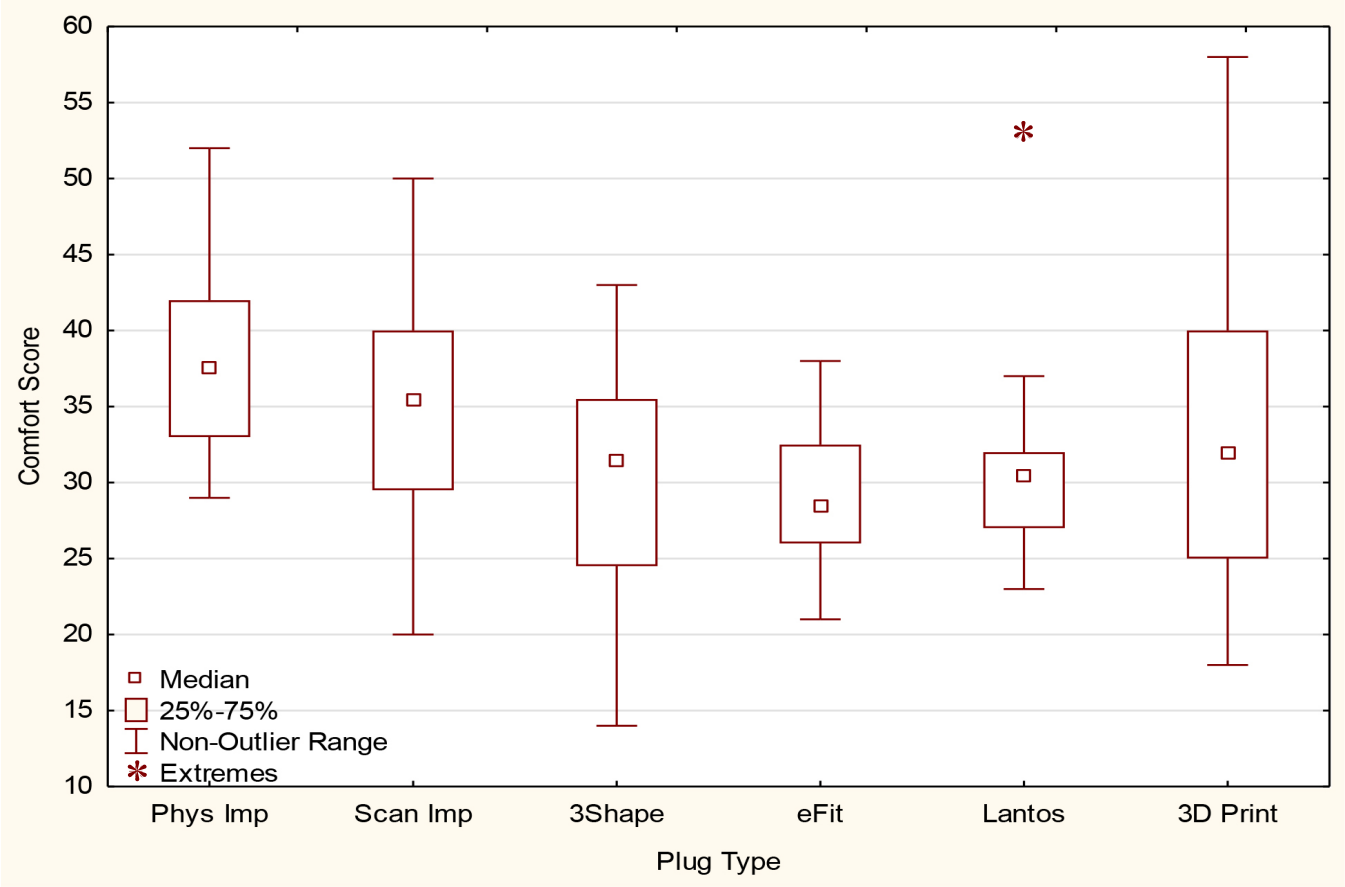

Figure 2. Comfort Scores by type of fabrication method, with lower numbers representing greater comfort. The lower box boundary represents the 25th percentile while the top box boundary represents the 75th percentile. Data points in the box represent the median. The vertical lines of the box represent the largest and smallest data points outside of the box. Extreme outliers denoted by an asterisk.

digital scanning fabrication methods, which depend on how well the scan was taken as well as the digital modeling and manufacturing processes. Thus, while earplugs made from physical impressions showed the highest average attenuation across subjects, there were earplugs within this group that were less attenuating than earplugs made from other fabrication methods. This means that on an individual basis, some earplugs made from digital scanning methods may be more protective than the traditional fabrication method for certain individuals.

Our results highlights the need for a recognized hearing conservation best practice, namely, to fit-test hearing protection on an individual basis (OSHA/NHCA/NIOSH Alliance, 2008). Therefore, individual fit-testing of custom earplugs should likely be performed regardless of the type of fabrication method. In this way, the hearing conservationist can assess the level of hearing protection provided to the individual and determine if the HPD meets the needs for that individual. If the HPD does not provide sufficient attenuation for the intended application, it can be sent back for modification or a new earplug may be needed, which may include new impressions and/or scans.

It is also worth noting that custom earplugs made from digital scans of physical ear impressions, an accepted method currently used by earplug manufacturers, were not significantly different from direct digital scanning methods. Thus, digital scanning methods can produce custom earplugs generally as protective as one currently accepted fabrication method. However, earplugs fabricated from scans of physical impressions were significantly less protective than earplugs made from physical impressions. This important finding may need further investigation and possibly refining of the modeling and manufacturing process of earplugs made from impression scans.

Another note, digital ear scanning methods, specifically Lantos and eFit®, may allow for capturing deep earcanal geometries more safely than could otherwise be obtained from physical impressions because they permit scanning up to millimeters from the tympanic membrane (TM). Moreover, deep physical impressions can often be uncomfortable to unbearable for many individuals. This is because an audiologist or hearing professional must insert an otoblock and silicone material deep within the earcanal,

which presses against the thin layer of skin in the bony portion of the earcanal. This can be very uncomfortable for some individuals and a riskier procedure (compared to scanning) when attempting to take impressions needed for deeply fitted highly attenuating earplugs. Additionally, if the otoblock is not placed properly or in the event of a blow-by, the silicone material may have a higher chance of contacting the TM, which can lead to complications. It is also worth noting that in our study of 24 subjects, 15% of them could not be suitably fitted with custom earplugs since ear anatomy or excessive cerumen prevented ear impressions from being made in this research protocol. However, in a clinical setting, subjects could likely have excessive cerumen removed to permit ear impressions and abnormal ear anatomy would be left to the judgement of the clinician.

Finally, it may also be helpful to note that the AURA™ and 3Shape PHOENIX™ systems used in this study were not commercially available at the time of the study. The AURA™ system used in this study scanned only the earcanal and not the outer ear. Lantos Technologies has since launched a commercially available system, the "Lantos L3DS-19" which the manufacture states can capture data of the outer ear, including the upper and lower concha, in addition to the earcanal. 3Shape A/S has also stated their system has been upgraded and improved since this study.

Conclusions

The objective of this study was to determine if digital ear scanning technologies could be used for the production of custom earplugs. The ear scanning technologies evaluated in this study were capable of capturing earcanal geometries and producing 3D models that could be used to create custom earpieces. Custom earplugs produced from digital scanning technologies and traditional methods were evaluated for hearing protection and perceived comfort. The results suggest custom earplugs made from digital scanning methods provide significantly less hearing protection, on average, than earplugs produced from physical ear impressions, but conversely that perceived comfort was significantly higher for custom earplugs made from digital scanning methods compared to traditional methods.

Digital ear scanning provides potential advantages over traditional methods such as reduced logistical hurdles (digital files rather than physical molds), reduced time to obtain a model of the ear, and reduced discomfort for subjects. Digital ear scanning technologies are capable of capturing sufficient information, generally less invasively, than traditional methods to create custom earplugs. According to this study, however, custom earplugs made from digital scans were not as protective as custom earplugs made from physical impressions. Thus, if custom earplugs are wanted or needed with maximum levels of hearing protection, the physical impression method is likely the best option for producing them. However, if maximum sound attenuation is not needed, or if a subsequent in-situ fit test is conducted to verify the attenuation of the custom earplug, or if sound attenuation is not important, for example, as may be the case for hearing-aid or communication earpieces, digital scanning methods may be preferred.

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