AES 58TH INTERNATIONAL CONFERENCE

Music-Induced Hearing Disorders

Aalborg, Denmark
28–30 June, 2015

Technical Council

Organized in association with the TC on Hearing Loss and Hearing Loss Prevention

Sunday, June 28 **10:00**

OPENING ADDRESS

10:30

PAPER SESSION 1: EFFECTS ON HEARING AND PERCEPTION PRODUCED BY EXPOSURE TO MUSIC

1-1 Effects of Sound-Induced Hearing Loss and Hearing Aids on the Perception of Music (Invited)—*Brian C.J. Moore,* University of Cambridge, UK

Exposure to high-level sounds, including music, produces a variety of physiological changes in the auditory system that in turn produce a variety of perceptual effects. Damage to the outer hair cells within the cochlea leads to a loss of sensitivity to weak sounds, loudness recruitment (a more rapid than normal growth of loudness with increasing sound level and a consequent reduced dynamic range), and reduced frequency selectivity. Damage to inner hair cells and/or synapses can lead to degeneration of neurons in the auditory nerve and hence to a reduced flow of information to the brain, even when audiometric thresholds remain normal. This leads generally to poorer auditory discrimination and may contribute especially to reduced sensitivity to the temporal fine structure of sounds and to poor pitch perception. Hearing aids compensate to some extent for the effects of threshold elevation and loudness recruitment by the use of multi-channel amplitude compression, but they do not compensate for reduced frequency selectivity or loss of inner hair cells/synapses/neurons. The multi-channel compression processing used in hearing aids can impair some aspects of the perception of music, such as the ability to hear out one instrument or voice from a mixture. The limited frequency range and irregular frequency response of most hearing aids is associated with poor sound quality for music. Finally, systems for reducing acoustic feedback can have undesirable side effects when listening to music.

1-2 Use of and Attitudes Towards Hearing Protection in the Sound and Music Industries: Results of a Pilot Survey—*Annie Jamieson*, University of Leeds, UK

Music-induced hearing loss (MIHL) is increasingly well-recognized as a problem, not just for audiences and musicians but also, though less well-reported, for sound engineers and other production professionals. While hearing protection technology is becoming increasingly effective, there remain concerns among professionals that their ability to perform their job will inevitably be affected by any form of protection. This paper reports the results of a pilot survey of 230 workers and students in the sound and music industries, examining attitudes towards hearing risk and protection and patterns of HP use.

1-3 Loudness Scaling Tests in Hearing Problems Detection—*Bozena Kostek, Piotr Suchomski, Piotr Odya*, Gdansk University of Technology, Gdansk, Poland

The number of people using portable audio players have increased significantly over recent years. This implies the rise in the number of people having hearing loss problems. Therefore, there is a need to find appropriate procedures that will simplify the process of hearing loss detection. Investigations performed show that audiometric tests may not be sufficient to assess hearing problems in young people. Contrarily, the obtained results indicate the importance of loudness scaling tests in the process of hearing loss measurements. A method for enhancing existing loudness scaling tests and its main features are described in the paper and compared with the LGOB (Loudness Growth in 1/2-octave bands) procedure. The comparison results are shown and discussed.

1-4 Hearing Measurements During Two Norwegian Music Festivals—*Tron Vedul Tronstad*, SINTEF ICT, Acoustics Group, Trondheim, Norway

Music festivals are a large contributor to leisure noise / sound exposure for many people. Several days with repeated attendance to concerts can put the ears to a test they might not handle. It is well known that concerts can give "cotton" in the ear, often accompanied with a ringing sound. These conditions, more formally known as temporary threshold shift and tinnitus, are often gone within the next day or days. Since music festivals consist of many concerts, the damage potential is even higher at festivals than single concerts. In this study eight music festival participants, at two different Norwegian festivals, measured their hearing both before and after each festival day. Hearing threshold levels and distortion product otoacoustic emis-

sion levels were measured. In addition each person wore a sound dose meter recording one minute equivalent levels. An exposure/response relationship is looked into, testing the equal energy hypothesis used in most occupational regulations and concert guidelines. The results show that the ears are really put to the test during music festivals, but also indicates that the hearing can cope with such exposures.

14:00

PAPER SESSION 2: DETECTION OF MUSIC INDUCED HEARING DISORDERS

2-1 A Retrospective on Studies on Cochlear Mechanics, Evoked Otoacoustic Emissions, and Prevention of Hearing Loss Due to Overexposure—A New Integrative Model (Invited)—*Eric LePage*, OAEricle Australia, Claremont, Australia; Facultes de Medecine et de Pharmacie, Equipe Biophysique Neurosensorielle, Clermont-Ferrand, France

Music-Induced Hearing Loss (MIHL) is a special case of noise-induced hearing loss (NIHL) so far as the methodology of quanitification is concerned, while it presents a particularly acute challenge in respect of general health issues. Our approach is to work on the definition of susceptibility of hearing loss by developing the notion of redundancy of the numbers of outer hair cells (OHC) required for normal hearing sensitivity. Otoacoustic emissions offer the ability to monitor the OHC population because they are primarily generated by OHC somatic motility. We are able to process click-evoked otoacoustic emission data to show that emission strengths may decline for years before there is any substantial hearing loss and this is in part because the emissions appear to deliver actually maps of activity, while pure tone audiometry appears to integrate such activity over a longer-length of the cochlear partition. Hence we reiterate the notion of hidden hearing loss originally developed by comparing emission levels with behavioural measures. We recast the active tuning function in spatial terms and suggest that OHC activity performs the "smart function" of focussing and/or defocussing of acoustic energy relative to a place which may vary as a result of many influences. Musical content is carried by the periodicity pitch and is less affected by structural and functional change.

2-2 Music and Musician Earplugs: Temporary Effects of Music Exposure while Wearing Hearing Protectors—*Annelies Bockstael, Hannah Keppler, Dick Botteldooren*, Ghent University, Belgium

Recreational music exposure is a potential risk factor for noise-induced hearing loss (NIHL). Standard hearing protectors can be worn to reduce the exposure level, but their typical attenuation characteristics, i.e., increasing attenuation with increasing frequency, might distort the music's spectrum and hence reduce the listening quality. Therefore, new augmented hearing protectors have been designed with modified attenuation characteristics to combine hearing protection and listening comfort. However, only few independent studies have assessed the performance of those augmented protectors in realistic exposure conditions. This study evaluates temporary effects on cochlear status after music exposure.

2-3 ER-10X Extended Bandwidth Research Probe System—*Steve Iseberg,*[1] *Jonathan Siegel,*[2] *Dan Mapes-Riordan,*[1] *Robert Cochran*[1]
[1]Etymotic Research, Inc., Elk Grove Village, IL, USA
[2]Northwestern University, Evanston, IL, USA

A new measurement system has been developed for hearing research. Targeted especially for otoacoustic emissions, it is flexible enough for a variety of tests. Performance improvements include extended bandwidth, reduced distortion, higher SPL up to 90 dB SPL, and lower noise. Traditionally, hearing research has been limited to 5 to 10 kHz, due to the difficulty of controlling acoustic pressure at the tympanic membrane. This system can be combined with Forward Pressure Level techniques for accurate prediction of SPLs up to 20 kHz. The system consists of a probe with three drivers and four microphones, along with appropriate amplifiers and the calibrator. This system can measure high frequency otoacoustic emissions as a potential indicator of early onset of hearing loss.

2-4 Design of an Acoustic Probe to Measure Otoacoustic Emissions Below 0.5 kHz—*Anders Tornvig Christensen, Rodrigo Ordonez, Dorte Hammershøi*, Aalborg University, Aalborg, Denmark

Our ability to hear is reflected in low-level acoustic signals emitted from the ear. These otoacoustic emissions (OAEs) can be measured with an acoustic probe assembly coupling one or more small loudspeakers and microphones into the sealed ear canal. The electroacoustic instrumentation of commercial probe systems allow for detailed studies of OAEs emitted between 0.5 and 6-8 kHz. Few studies report OAE measurements below 0.5 kHz. This paper is a preliminary report of an OAE probe aimed at making OAE measurements from 0.03 to 3 kHz. The range 0.5-3 kHz was included to study lower-frequency OAEs with reference to standard-range OAEs.

Monday, June 29 **08:30**

PAPER SESSION 3: HEARING AID TECHNOLOGY FOR MUSIC AND TREATMENT

3-1 New Opportunities for Hearing Impaired Music Lovers (Invited)—*Nikolai Bisgaard*, GN Resound as, Ballerup, Denmark

Hearing aids have come a long way in providing significant improvements in general sound quality as well as signal processing features for optimum sound delivery in view of the hearing loss of the user. Working under very serious constraints both in size and power supply, highly sophisticated and custom designed DSP systems are used to implement directional microphone systems, noise reduction as well as feedback suppression in order to emphasize the very important speech signals. Some of these processing schemes are not always desirable for music presentation and special set-ups must be made available to reach good sound quality on music reproduction. Recently, it has been accomplished to implement wireless connectivity between hearing aids and remote devices including mobile phones. This has started a new era where the utility of hearing aids has been significantly enhanced. An overview of the state of art technology in the field of hearing aids as well as the future perspectives will be given.

3-2 Music Technology for Tinnitus Treatment within TINNET—*Jaime Serquera,*[1] *Winfried Schlee,*[1,2] *Rüdiger Pryss,*[3] *Patrick Neff,*[4,5] *Berthold Langguth*
[1]Tinnitus Research Initiative (TRI)
[2]University of Regensburg, Germany
[3]Ulm University, Ulm, Germany
[4]University of Zurich, Zurich, Switzerland
[5]University of the Arts (ZHdK), Zurich, Switzerland

Overexposure to loud music can cause tinnitus, but musi-

cal stimulation at a well adjusted loudness level can be also a key strategy for its treatment. In this conference on Music Induced Hearing Disorders, we report on our music-based technologies for tinnitus treatment. In this context, we introduce TINNET, an EU-funded multidisciplinary network currently investigating, among others, the effect of these technologies on different tinnitus subtypes. TINNET also focuses on the identification of clinical characteristics, neuronal correlates, and molecular genetics of these subtypes. Furthermore, we present the results of a pilot study funded by TINNET. The study evaluated the effect of a novel sound therapy highly rooted on music technology. The study revealed promising results and it also identified a crucial problem experienced by the patients: Due to their lack of appropriate ear training, it was difficult for them to perform an accurate pitch match. To address this challenge, we present our approach aiming at developing a set of tools for ear training. We propose such training to be essential to effectively apply any therapy which relies on a precise pitch match.

3-3 Programming Hearing Aids for Musical Purpose—*Esther Rois-Merz*, Audienz – musikalische Hörberatung e.U., Vienna, Austria

Musicians suffering from hearing loss are scared to lose what is the most important for them: making and listening to music. They dispose of very educated and trained hearing capacities. Especially when talking to sound engineers or piano tuners, technical specifications of hearing aids can easily be checked. The most disadvantaged musicians in terms of hearing aid adjustment are still the singers. They suffer from occlusion and produce very loud sounds inside their heads. And in the pause, they need to understand the conductor. Music is very variable, and so should be the fitting strategy of the audiologist who programs their hearing aids.

11:00

PAPER SESSION 4: SOUND LEVEL MANAGEMENT AND CONTROL

4-1 Amplified Music and Sound Level Management: A Multi Stakeholder Perspective—*Johannes Mulder*, Murdoch University, Perth, Western Australia

Music induced hearing disorders and noise pollution are issues that emerge on the crossroads of society, technology, and culture. Health aspects, as well as personal preferences inform the debate, policymaking, and application of technologies, but in doing so the different stakeholders have to consider multifaceted nature of the issues. Rigorous application of strict rules inevitably leads to the closure of music venues, damaging the valuable live music industry. This paper argues that multidisciplinary approaches are required to reduce hearing risk at music concerts and related problems of noise pollution. From a broad look at the issues at large the paper segues to a narrow perspective looking at the interactions between stakeholders "on the floor." The paper argues that even though noise regulations and hearing risk mitigation policies may be different between nations and states, best practices originate from procedures and policies that are developed from an understanding of the multiple stakeholder perspective and that facilitate dialogues between the different agents involved.

4-2 Sound Level Measurements and Control at Large Dance Events—*Marcel Kok*, dBcontrol, Zwaag, The Netherlands

Large outdoor dance events are increasingly popular in the Netherlands and Belgium. Environmental rules and laws and covenants to prevent hearing damage have lead to serious measurements and control of the sound field. From the simple sound level meter twenty years ago to a sophisticated measurement network nowadays. This paper contains an overview of the developments and some detailed insights how sound control works nowadays.

4-3 Soundlevel Measurements Made EaZy: 10EAZY—Intuitive SPL Monitoring for Live Sound Events—*Jacob Navne*, Inventor of 10EaZy; SG Audio Aps

As health and safety concerns for audience and neighboring residential areas enters into the realm of live music events like concert venues, outdoor festivals as well as dance and DJ events, the industry is facing more and more sound level regulation. A number of these regulations does not allow room for musical events, as their purpose is to limit noise nuisance, but a music event produces noise in abundance—the actual music performed. This is an ongoing challenge for event organizers and ultimately threatens the festival or venue's existence. 10EaZy is a sound level measurement solution striving to make the ends meet in a non-perfect world. 10EaZy provides an extremely intuitive graphical interface that speaks the language of sound engineers or DJs to let them know how loud they are and combines this with accurate and IEC compliant custom hardware. Unintended changes in overall SPL during a performance is noticeable to the audience and disruptive to the listening experience. An algorithm in 10EaZy predicts and clearly display the average over time to avoid disruptive level reductions. A clear indication of SPL have proven a number of times to have a preventive effect on the SPL, as simply knowing how loud a given show is, will drive the sound engineer to try and achieve a better sounding show at a lower SPL.

4-4 An Investigation of the Sound Pressure Level at the Roskilde Festival—*Carsten Borg*, Oticon A/S, Smørum, Denmark

This paper describes the development of a small and convenient measurement system used for measuring the sound pressure level (SPL) at rock festivals. Over the years more than 500 test persons have worn the measurement system and thus contributed significantly to the data collection. Via a dedicated software tool suite, statistical analysis can be performed on the measurement data. Examples of measurement data are shown and discussed.

Tuesday, June 30 **08:30**

PAPER SESSION 5: HEARING PROTECTION IN THE MUSIC INDUSTRY

5-1 New Developments in In-Ear Monitor (IEM) Technology For Musicians With Hearing Loss (Invited)—*Heather Malyuk,*[1] *Robert Schulein,*[2] *Michael Santucci*[1]
[1]Sensaphonics Hearing Conservation, Chicago, IL, USA
[2]ImmersAV Technology, Schaumburg, IL, USA

For musicians with hearing loss, hearing aids are the primary, and often only, option for needed amplification while performing. Even with decades of technological improvements, limitations in hearing aids for performing musicians continue to exist with respect to frequency response, distortion, and restricted dynamic range. Hearing aids are

primarily designed to improve speech understanding in a variety of real world situations, while at the same time being very small in size with low power consumption. Although music appreciation can be important for hearing aid users, high fidelity performance is generally considered to be of secondary design importance. Modern hearing aids use digital technology to optimize performance under a wide variety of real world conditions. Examples include the management of adaptive directional microphones, automatic wind noise reduction, and adaptive noise filtering. While such circuits can significantly improve speech understanding, they do so at the expense of creating audible non-musical artifacts that are apparent while listening to music. For the performing musician the functional objectives of a hearing improvement device are quite different in that wide dynamic range and low distortion sound reproduction are of paramount importance, and to a lesser degree size and battery life.

In-Ear-Monitoring (IEM) systems using low distortion transducers with wide frequency range have been available for some time and can serve as a partial solution to the needs of the hearing impaired musicians. This paper reports on performance improvements for such musicians obtainable by combining a high performance IEM, that includes binaural ambient microphones, with external electronic signal processing that address hearing threshold loss, recruitment, and maximum comfortable listening levels. Detail of the process will be presented along with several case studies of musicians that currently use and help design the compensation methods.

5-2 Towards a Better Hearing Protection Experience for Musicians: Music Filters and Acoustic Leakage Tester—*Pieter Van 'T Hof*, Dynamic Ear Company, Delft, The Netherlands

Musicians are exposed to high sound levels. The levels are so high that this will inevitably lead to hearing loss or Tinnitus over a number of years. Musicians are aware of this, yet most do not wear adequate hearing protection because they can be uncomfortable to wear, lead to occlusion, have a bad acoustic transfer function, and a poor acoustical seal. DEC has been providing hearing protection solutions for the first three issues over the last five years in both universal and custom fitted earpieces. Nowadays the acoustical seal is commonly tested by applying air pressure [*sic*] . . . with comes with certain disadvantages. In this article we present a way of testing the acoustical seal by means of an acoustic leakage tester. Together with a control device to control the system, the leakage tester comprises a housing with a signal generator for providing an acoustical signal and a microphone for measuring it. During the measurement, the housing is inserted in the earpiece under test and the earpiece fit is tested in the ear. Changes in the measured sound pressure level provide a measure for the acoustical seal quality. Especially for musicians this is relevant as solutions DEC makes available provide low frequency attenuation and for proper functioning this requires a sufficient acoustical seal.

5-3 Directional Characteristics for Different In-Ear Recording Points—*Anders Kalsgaard Møller,*[1] *Flemming Christensen,*[1] *Pablo Faundez Hoffmann,*[2] *Dorte Hammershøi*[1]
[1]Aalborg University, Aalborg East, Denmark
[2]Now at Huawei Technologies Duesseldorf GmbH, Munich, Germany

An earphone system, that enables the listener to hear the sound sources and acoustics of the surroundings as close to real life as possible, are presented. The capture of the surrounding sound is achieved by mounting a microphone on the outside of earphones and simultaneously record and play-back the sound. In this paper measurement with different in-ear recording positions are conducted on nine subjects. The measurements are used for finding the optimal microphone position. The results showed that spatial information can be preserved up to around 4–5 kHz.

11:00

PAPER SESSION 6: HEADPHONE SOUND EXPOSURE AND MEASUREMENT STANDARDS

7-1 Prevention of Hearing Loss from the Use of Personal Music Players (Invited)—*Thomas Lund,* TC Electronic A/S, Risskov, Denmark

Millions of people are estimated to be at the risk of developing early hearing loss (HL) as a result of listening to personal media players (PMPs). Legislation now mandated by the European Commission has successfully brought down the SPL from PMPs sold in Europe but with the adverse effect that music and other content not produced like modern pop no longer can be played loudly enough to be heard under typical listening conditions. The current status is summarized and methods to reduce false negative and false positive user-warnings are proposed. Improved sound dose estimation in PMPs may furthermore help stem the "Loudness Wars" in music, thereby also protecting music heritage.

7-2 Dose Estimate by Personal Music Players Based on Weighted Output Voltage—*Dorte Hammershøi, Rodrigo Ordoñez, Anders Tornvig Christensen,* Aalborg University, Aalborg, Denmark

The exposure by personal music players may in future be displayed to users, as described in the current draft of EN 50332-3. The suggested procedure includes a weighting of the electrical output voltages of the music player and does not include the significance of the earphone sensitivity. It doesn't include the weighting principles necessary for sound sources close to the ears either, which constitutes an inverse head-related transfer function for either free- or diffuse field. The purpose of the present study is to assess the uncertainties in the dose estimate determined this way. Measurements for 20 earphones are included, and free- and diffuse field equivalent levels determined according to ISO 11904-2.

7-3 The Acoustical Significance of Age-Dependent Ear Elongation—*Flemming Christensen,* Aalborg University, Aalborg, Denmark

Elderly people, especially some old men, appear to have very large ears. This paper presents an investigation on the acoustic significance of the age dependent ear elongation. HRTFs and ear lengths were measured for two groups of young and old people. The older groups had larger ears on average, corresponding to what is reported in the literature. For female ears, virtually no acoustical effect was found. For male ears directional dependent effects in the range up to 5 dB on average was found for certain directions and frequencies. Implications on age dependent hearing loss (presbycusis) and measurements thereof are discussed.