

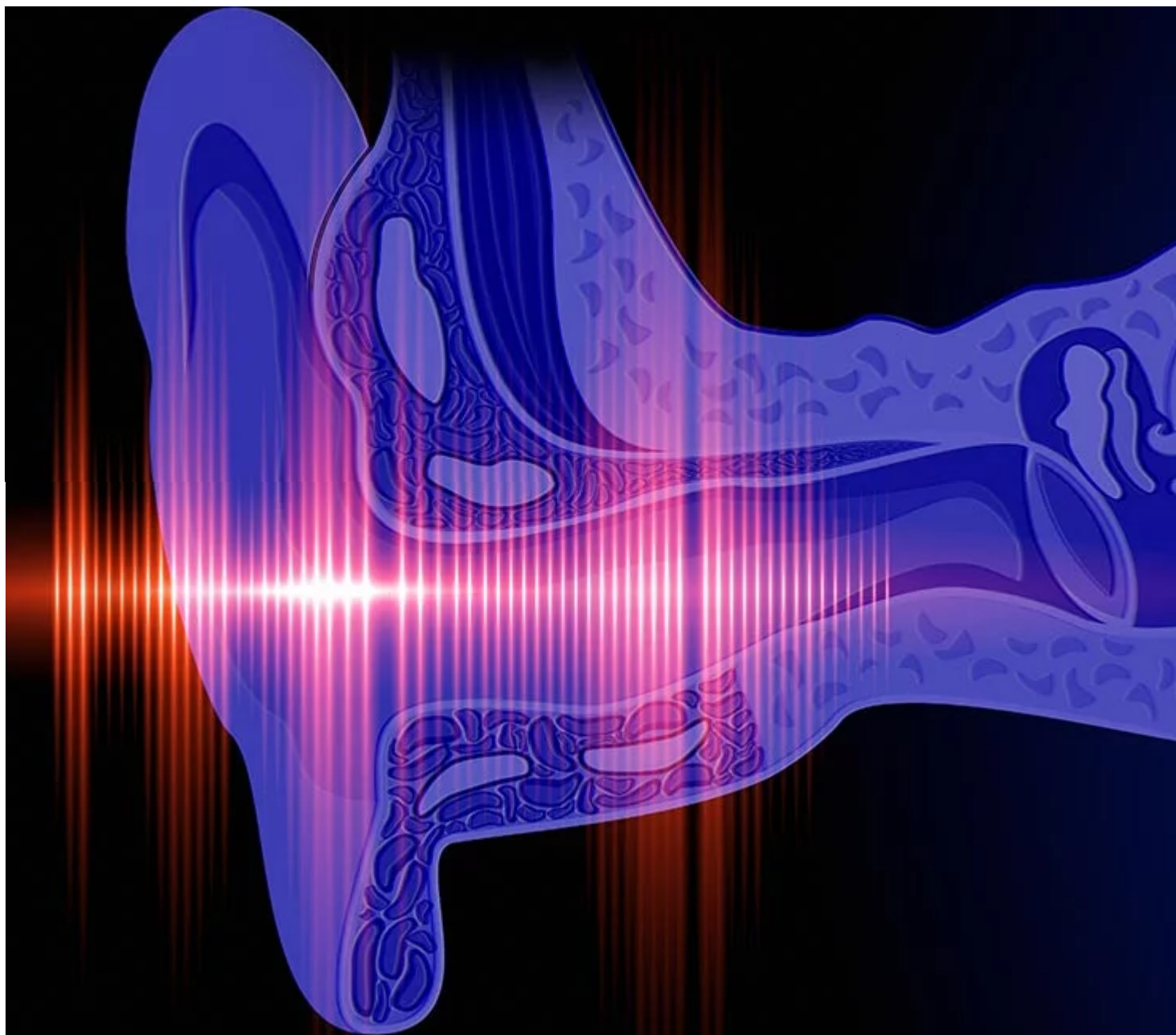


Research article
HEALTH

Otoacoustic Emissions: an Objective Measure of Hearing Health

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SUMMARY

Despite efforts to integrate hearing conservation programs into the workplace, noise-induced hearing loss remains the number one cause of disability among North American workers. To better assess the risk in the workplace, changes in workers' hearing health can be correlated with the level of ambient noise. The purpose of the study presented below is to develop an approach to improve hearing conservation practises by continuously monitoring otoacoustic emissions.

Introduction

Every year, more than 22 million workers (NIOSH, 2016) are exposed to daily noise that can lead to significant short or long term hearing loss. Despite the efforts of occupational hearing conservation programs, noise-induced hearing loss remains the most common cause of work-related disability, accounting for 72.5% of registered accepted cases (CNESST, 2017). The means of prevention currently used in industry are outdated and based on historical data that do not necessarily reflect the latest findings related to the functionality of the auditory system. Unfortunately, the intervals between screening and follow-up tests are too long to be able to detect hearing disorders in time, before they become permanent.

Otoacoustic emissions

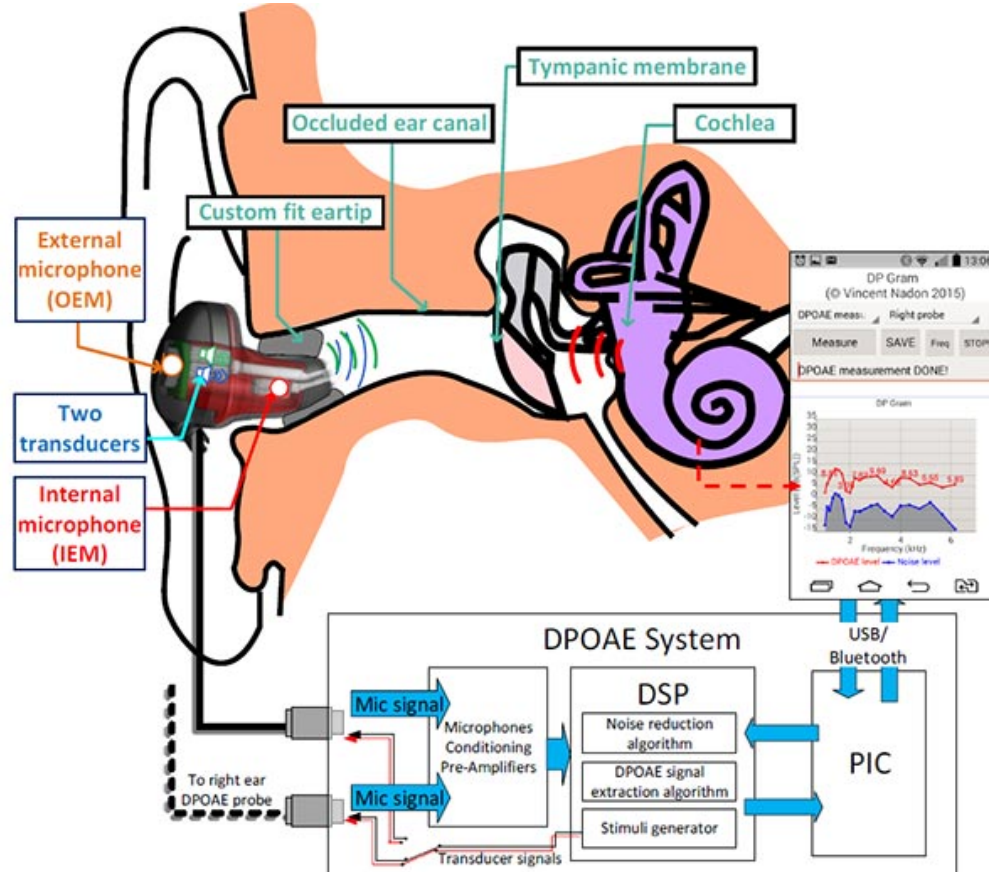


Fig. 1 Representation of the ear with the otoacoustic emission measurement system.

A new auditory health monitoring technique has been integrated in a portable system designed for industrial use. This technique is based on the measurement of otoacoustic emissions, “oto” meaning of the ear, as presented in Fig. 1. These emissions are small sounds emitted (in red) by the cochlea from inside the inner ear, which can be evoked by a miniature speaker and captured using a small microphone positioned in the occluded ear canal. The sound pressure level of these otoacoustic emissions, measured here with the distortion product otoacoustic emission (DPOAE) technique, indicates the health status of the outer hair cells (Fig. 2). The role of these cells has been discovered recently in the history of audiology, and their function is to amplify or reduce the movement of the basilar membrane, which is then transformed into an electrical signal by the inner hair cells to be sent along the auditory nerve to the auditory cortex, in the brain. When the outer hair cells are affected by noise exposure, the level of otoacoustic emission decreases. It can therefore be deduced that the noise dose received has been harmful to the hearing health. The DPOAE measurement technique has been used for several years already, but recently its use is more frequent and of greater interest in getting more information on hearing health, especially for the inner ear.

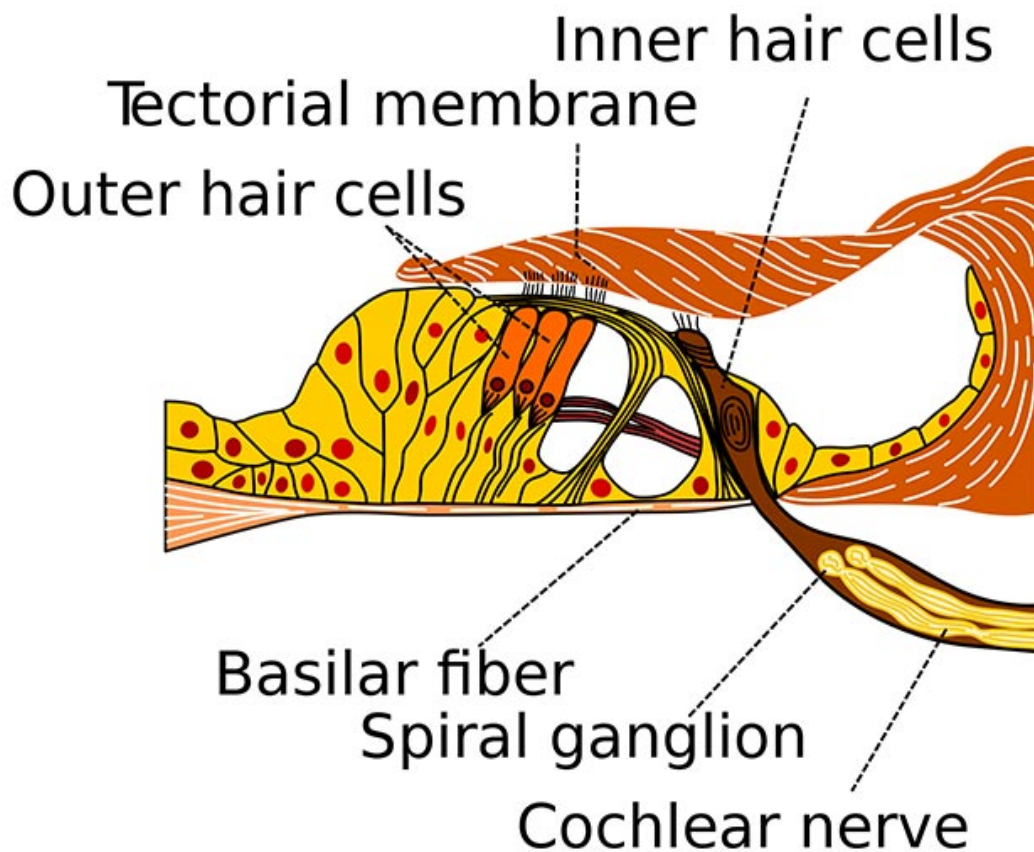


Fig. 2 Organ of Corti in the human ear cochlea

The combined use of a noise dosimeter to measure the sound level of the noise to which the worker is exposed and the measurement of otoacoustic emissions to evaluate the effect of this exposure, gives the possibility to determine the exact causes of hearing loss in an industrial setting and, eventually, prevent it by establishing a personalized maximum dose for each worker based on the changes observed during their previous working day.

Preliminary study

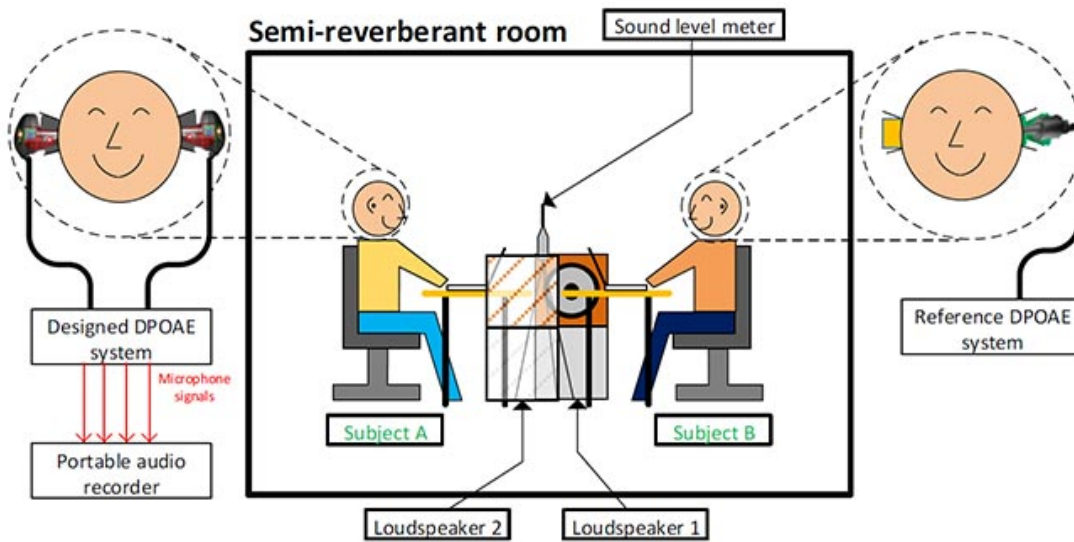


Fig. 3 Illustration of the experiment conducted on participants. The designed system is compared to a reference DPOAE measurement system

A preliminary study was conducted on participants (Fig. 3) with a first portable prototype (Fig. 1) (Nadon, Bockstael, Botteldooren, & Voix, 2017) designed to measure their otoacoustic emissions in a noisy environment where the average sound level can vary between 65 and 75 dB (SPL). As part of the study, participants were exposed to various types of noise up to 90 dB(SPL), such as industrial noise and broadband noise—also known as white noise—as well as a control condition, without noise. A typical day of noise exposure is presented at the top of Fig. 4.

Results of the Preliminary Study and the Developed Model

The effect of the noise dose on participants' hearing health is presented at the bottom of Fig. 4. DPOAE levels are lower after approximately 325 minutes (5 hours 25 minutes) of noise exposure and increase gradually during the recovery phase, which extends to the 375th minute approximately. The results of the study have defined a model that shows the effect of noise on the ear (Fig. 5) and to better observe the onset of hearing loss in humans. This model also makes it possible to assess the recovery rate of the ear following short-term trauma. This study supports the latest research on so-called "hidden" hearing loss (Lieberman & Kujawa, 2017) by observing changes in auditory function not measurable by the audiogram (the traditional hearing test) thanks to otoacoustic emissions.

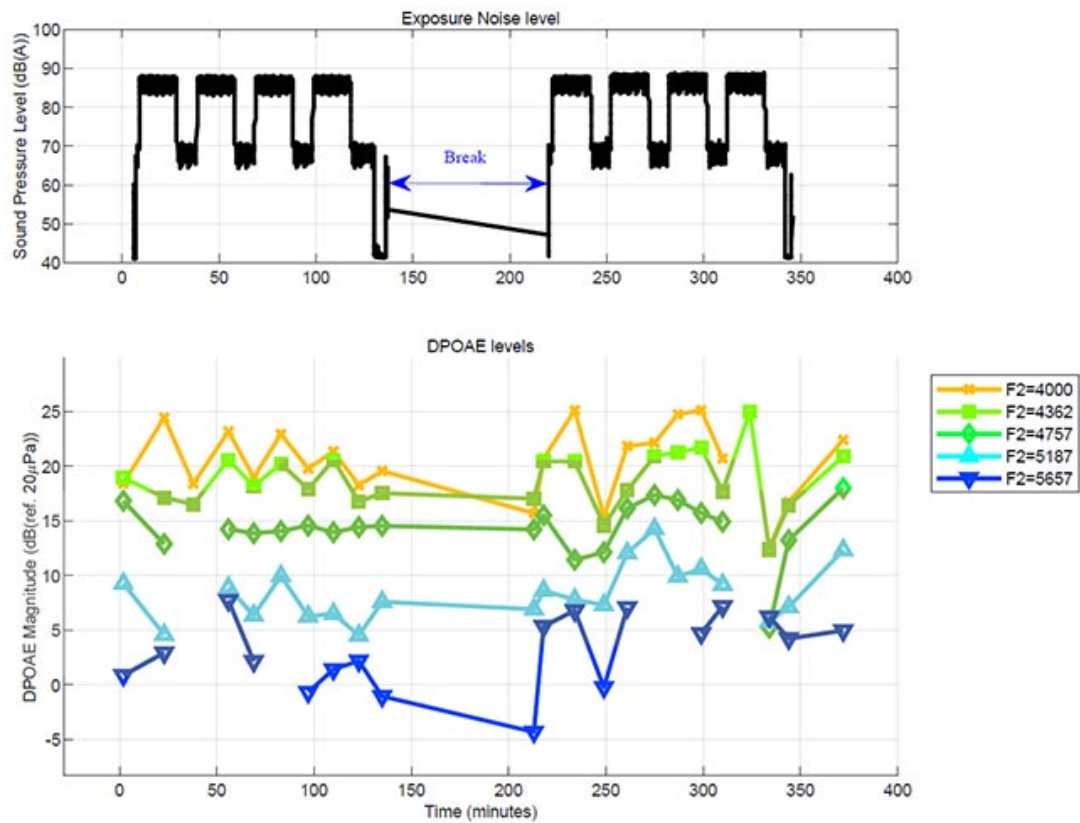


Fig. 4 Top: noise levels to which participants were exposed. Bottom: levels of otoacoustic emissions at different f2 frequencies (in Hz) of stimulation as a function of time. Some data points were rejected due to the high noise levels.

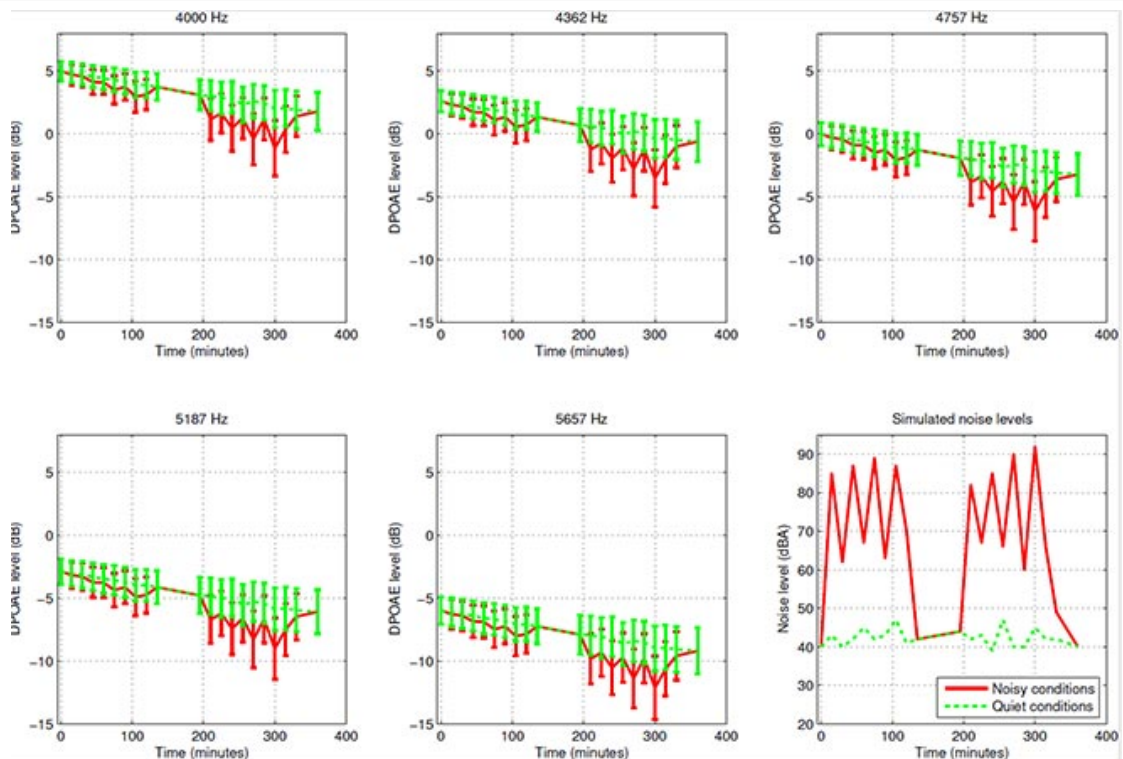


Fig. 5 Data simulated using the model identified from the data obtained during experimental tests. The onset of the hearing loss is presented according to the f2 frequencies (4000-5667 Hz) and the simulated noise level is presented at the bottom right.

Conclusions

Unfortunately, hearing loss entails high costs for society, particularly for the coverage of hearing aids and the various health care services involved.

The results of the preliminary study indicate that it is possible to establish a dose-response relationship between the noise dose to which participants are exposed and its effects on their hearing health. This way, it will be possible to establish personalized exposure limits for workers and, at the same time, prevent noise-induced hearing loss.

Vincent Nadon and Professor Jérémie Voix are currently testing a second version of the portable system, allowing more advanced otoacoustic emissions tests. The results are collected from a control group with low noise exposure levels and compared with a group working in an industrial environment and exposed to moderate noise levels.

Additional Information

For more information, please refer to the following article:

Nadon, V., Bockstael, A., Botteldooren, D., & Voix, J. (2017). Field Monitoring of Otoacoustic Emissions During Noise Exposure: Pilot Study in Controlled Environment. *American Journal of Audiology*, 26(3S), 352.



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References

CNESST. (2017). Statistiques annuelles 2017.

Lieberman, M. C., & Kujawa, S. G. (2017). Cochlear synaptopathy in acquired sensorineural hearing loss: Manifestations and mechanisms. *Hearing Research*.

Nadon, V., Bockstael, A., Botteldooren, D., & Voix, J. (2017). Field Monitoring of Otoacoustic Emissions During Noise Exposure: Pilot Study in Controlled Environment. *American Journal of Audiology*, 26(3S), 352.

NIOSH. (2016, juillet). National Institute for Occupational Safety and Health : NOISE AND HEARING LOSS PREVENTION.

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