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Research Article

Extended High-frequency Smartphone Audiometry as an Early Indicator of Auditory Fatigue in Call Centre Operators

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Abstract

Introduction: The study aimed to determine whether extended high-frequency (EHF) smartphone audiometry may be used as an early indicator of auditory fatigue in call centre operators.

Materials and Methods: A repeated-measures research design was selected to compare results of conventional frequency and EHF smartphone audiometry within the same participants, before and after an eight-hour work shift. Audiometric testing was performed in 50 participants aged 19 to 30 years (mean ± standard deviation: 24.8 ± 2.9 years), the participants were all employed at the company for six months (50%) or longer (50%). No health conditions, exposure to ototoxic medication, or previous exposure to occupational noise were reported. Participants completed a questionnaire regarding medical history, perception of hearing, noise and habits in the call centre, and fatigue. Ambient noise levels in the call centre were measured in the call centre at different times during the day for five consecutive days.

Results: Findings revealed statistically significant temporary threshold shifts (TTS) at 500 Hz, 1 000 Hz, 3 000 Hz, 12 500 Hz, and 16 000 Hz ranging from 5 to 20 dB. Changes in thresholds occurred after an eight our work shift in the call centre. Noise-level measurements indicated ambient noise levels in the call centre environment ranging from 64 to 85.3 dBA. Hearing-related symptoms including aural fullness and otalgia (46%), tinnitus (54%), and sensitivity to loud noises (48%) were reported by call centre operators.

Conclusion: Prolonged exposure to auditory stimuli at moderate intensity levels through the headset together with high ambient noise levels and minimal breaks in between calls may result in auditory fatigue followed by TTS in conventional and extended high frequencies.

Keywords: Call Centre; Auditory Fatigue; Extended High Frequency (EHF); Temporary Threshold Shift (TTS)

Introduction

The call centre industry in South Africa has grown exponentially over the past few years. Since 2013, the South African call centre industry has increased by 8% per annum. Call centres in South Africa create up to 54 000 job opportunities for individuals and the contribution of this industry to the country's gross domestic product is measured at 0.92% [1]. The average call centre operator endures an eight-hour long shift of noise exposure from his or her headset per day, and the effects of environmental noise for several years [2].

Environmental noise exposure in call centres can be divided into four categories: human activity, office equipment, indoor installations, and outdoor activity. An indication that environmental noise may influence noise exposure in a call centre is when operators adjust the intensity of their headsets as the environmental noise increases to enhance the signal-to-noise ratio (SNR) [3]. Communication received through the headset at a high volume increases the strain on the auditory system, resulting in auditory fatigue. Therefore, environmental noise levels have a direct and indirect effect on noise exposure among call centre operators. It is crucial to consider the duration, frequency, and intensity of the stimuli and environmental noises that may determine whether operators are at risk to develop auditory fatigue after an eight-hour shift.

Physiologically, auditory fatigue may be attributed to increased flexibility of the stereocilia after moderate noise exposure. Swelling of the outer hair cells (OHCs) occurs due to prolonged noise exposure. This leads to glutamate excitotoxicity which contributes to peripheral auditory fatigue [3].

Prolonged exposure to moderate intensity may not only result in TTS but is a risk factor for permanent damage to the auditory system. Research has suggested that excessive noise exposure may lead to early neural degeneration which may affect the neural synapses between cochlear inner hair cells and nerve terminals. Cochlear synatopathy may not be diagnosed by electrophysiological and behavioural evaluations while still in a mild or moderate stage. This explains why conventional audiometry is not sensitive enough to identify mild cochlear synatopathy which contributes to difficulty with speech perception in noise, tinnitus, and hyperacusis [4].

A research study involving conventional and EHF audiometric testing in call centre operators has found that the hearing threshold levels (HTLs) at 125 to 3 000 or 4 000 Hz in call centre operators were knowingly higher than in individuals who were not exposed to noise, but they performed similar to or better than predictions at extended high frequencies of 9 000 to 12500 Hz [5].

Prolonged noise exposure may also affect EHF from 10 000 Hz to 14 000 Hz together with conventional high frequencies from 3 000 Hz to 6 000 Hz [6]. Although speech perception is dominated by lower frequency hearing, EHFs play a vital role in speech perception, especially in background noise, and a hearing loss affecting EHFs may contribute to listening difficulties [7]. EHF audiometry may be used for early identification and intervention of hearing loss due to noise damage.

The objective of this study was to determine whether EHF smartphone audiometry may be used as an early indicator of auditory fatigue in call centre operators.

Materials and Methods

The study was conducted in call centre operators, including a questionnaire, conventional frequency smartphone audiometry (500 Hz - 8 000 Hz), EHF smartphone audiometry (8 000 Hz - 16 000 Hz), as well as noise level measurements.

Questionnaire

The participant group comprised 28 females and 22 males; therefore, in total, 50 participants were part of this study. The selection criteria specified that participants had to be between the ages of 18 and 30 years to limit the effect of age-related changes to the auditory system. All the participants in this study were between the ages of 19 and 30 years [mean ± SD = 24.8 ± 2.9 years]. The participants were all employed by the same company for six months to a year (50%) or longer (50%). No health conditions, exposure to ototoxic medication, or previous exposure to occupational noise were reported.

More than half of the call centre operators (54%) used the Mairdi single-ear headset with a microphone, and the remaining used various kinds of single-ear and circumaural headsets with microphones, including Sennheiser and JVC. There were more single-ear headset users who preferred to put the headset on the right ear (36%) to the left ear (24%), and only (6%) put the headset alternately on both ears. Most of the call centre operators (74%) used the telephone for more than 6 hours per day. Although the overall response of callers was perceived as friendly, frequent calls occurred where individuals were either screaming or making loud noises into the receiver (20%).

More than half (54%) of the call centre operators were exposed to noise outside the work environment, and almost two thirds (59%) were exposed to this daily. Noise exposure outside the work environment included listening to music (56%), environmental noise (37%), and hobbies (7%) such as hunting and motor racing.

Less than a third (32%) of the call centre operators reported changes in hearing since working at the call centre, but there were various ear-related complaints. Aural fullness and otalgia were reported (46%). More than half (54%) experienced tinnitus and sensitivity to loud noises since working at the call centre. Fatigue since working at the call centre was reported by a majority of operators (64%). More than two thirds (72%) reported taking breaks between calls, mostly after three or more calls (84%), which improved focus, relieved anxiety, and reduced discomfort of the ears.

Long hours of telephone usage, together with minimal and short breaks and noise exposure outside the work environment may have contributed to ear-related complaints such tinnitus, aural fullness, sensitivity to loud noises, otalgia, and perceived changes in hearing.

Conventional frequency smartphone audiometry

The Samsung Galaxy J2, using Android version 5.1.1 as the operating system, was used to determine conventional frequencies (500 Hz-8000 Hz). The hearTest application version 5009 allows for automated threshold determination at conventional-frequency ranges (500 Hz-8 000 Hz). The SANS 10083 Occupational Health Baseline protocol was selected as it includes the inter-octave frequencies 3 000 Hz and 6 000 Hz. Acoustic stimuli were presented through HD 280 PRO circumaural headphones during conventional-frequency testing.

Extended high frequency smartphone audiometry

The Samsung Galaxy A3, using Android version 8.0.0 as the operating system, was used to determine extended high frequencies. The hearTest application version 5009 allows for automated threshold determination at extended high-frequency ranges (8 000 Hz-16 000 Hz). Acoustic stimuli were presented through Sennheiser HDA 300 circumaural headphones during extended high-frequency testing.

Noise level measurements

The Rion NA-24 sound-level meter was used to monitor sound levels during the data collection process. The sound-level meter was also utilized to measure ambient nose levels in the call centre at different times during the day for five consecutive days.

Procedures

If results of the otoscopic examination, acoustic immittance measurements, and conventional- frequency smartphone audiometry were normal, as per selection criteria, extended high-frequency smartphone audiometry was conducted. Normal results suggest that no abnormalities were detected during the otoscopic examination; normal static compliance (0.3-1.6 ml), ear canal volume (0.5-1.5 ml), and ear canal pressure (-50-50 daPa) results were obtained; at least one present acoustic reflex measurement was obtained during the acoustic immittance test; and the thresholds obtained during conventional-frequency smartphone audiometry were 25 dB or lower [8]. Conventional-frequency audiometry could only be assessed down to 10 dB which was the lowest intensity available to measure hearing thresholds with the smartphone. The range of normal hearing assessed with the smartphone was 10 to 25 dB.

Pure tone air conduction thresholds were determined for 8000 Hz, 10 000 Hz, 12 500 Hz, and 16 000 Hz in each ear for all participants, using extended high-frequency smartphone audiometry. The same test was repeated after five minutes to ensure accurate results and internal consistency. Conventional-frequency and extended high-frequency smartphone audiometric assessments were repeated after a full day shift to obtain post-shift hearing thresholds. At the end of a work day, participants had been exposed to noise levels from their headsets and the call centre environment for eight hours. Both assessments were conducted twice, five minutes apart.

Participants were re-assessed within one week of the initial assessment. No control group was used in this research study as the design warranted within-subject measurements. Re-assessment within a week allows subjects to act as their own control and eliminates the possibility of within- subject differences [9]. The reassessment improves the overall reliability of the results obtained in this study if the test-retest reliability between the initial assessment and re- assessment is satisfactory.

Noise monitoring was constantly performed during assessments to ensure that A-weighted equivalent-continuous sound pressure levels of background noise did not exceed 35 dBA [5].

This procedure was performed identically in the morning (pre-shift measurements) and late afternoon (post-shift measurements).

Results

Pre-shift and post-shift measurements: Initial assessment

The most significant shifts in thresholds measured during the initial assessment, in the conventional frequencies, occurred at 500 Hz in the right ear (13.9 ± 4.1; 17.8 ± 6.4) and left ear (14,8 ± 4.2; 19.1 ± 7.2), 1 000 Hz in the right ear (12.3 ± 3.2; 14.1 ± 4.6) and left ear (12.5 ± 3.4; 14.8 ± 4.6), 3 000 Hz in the right ear (11.6 ± 3.1; 13.5 ± 5.1) and left ear (12.1 ± 3.7;13.6 ± 4.7). In the extended high frequencies, the most significant changes occurred at 12 500 Hz in the right ear (12.9 ± 7.0; 15.0 ± 9.8) and the left ear (13.5 ± 8.7; 15.6 ± 10.3), and at 16 000 Hz in the right ear (21.8 ± 12.2; 23.9 ± 13.1) and the left ear (20.9 ± 12.2; 23.3 ± 12.9).

Pre-shift and post-shift measurements: Re-assessment

The most significant shifts in thresholds measured during the re-assessment, in the conventional frequencies, occurred at 500 Hz in the right ear (14.0 ± 4.0; 18.3 ± 6.5) and left ear (14,6 ± 4.4;19.3 ± 7.1), 1 000 Hz in the right ear (12.0 ± 3.0; 14.6 ± 4.6) and left ear (12.4 ± 3.4; 15.3 ± 4.8), 3 000 Hz in the right ear (11.6 ± 3.3; 13.0 ± 4.6) and left ear (11.9 ± 3.5; 13.7 ± 5.2). In the extended high frequencies, the most significant changes occurred at 12 500 Hz in the right ear (13.7 ± 7.4; 15.6 ± 9.7) and the left ear (13.5 ± 9.5; 15.5 ± 11.0), and at 16 000 Hz in the right ear (21.5 ± 12.1; 24.3 ± 13.2) and the left ear (20.9 ± 12.1; 23.8 ± 13.4).

Figure 1: Initial assessment pre-shift and post-shift results for conventional and extended high-frequency smartphone audiometry.

Figure 2: Re-assessment pre-shift and post-shift results for conventional and extended high frequency smartphone audiometry.

Test re-test reliability

The intraclass correlation coefficients (ICC) for the initial assessment equals 0.952. According to Cicchetti [10], ICC values between 0.75 and 1.00 are excellent. Thus, the test-retest reliability for the initial assessment could be considered excellent. According to the 95% confidence interval, there is a 95% chance that the ICC falls between 0.945 and 0.957. The p-value for the ICC is less than 0.001 (sig. = 0.000) which indicates that the ICC is statistically significant.

The test-retest reliability for the re-assessment could also be considered excellent. According to the 95% confidence interval, there is a 95% chance that the ICC falls between 0.946 and 0.958. The p-value for the ICC is less than 0.001 (sig. = 0.000) which indicates that the ICC is statistically significant.

Ambient noise-level measurements in the call centre

Noise levels were measured over a period of five days, in the same location, at the same time each day. The specific locations were selected for the measurements and an average was calculated for each day.

Measurements were obtained at nine o' clock in the mornings and four o'clock in the afternoons. The average of the ambient noise levels measured in the mornings was 64 dBA and in the afternoons

Figure 3: Average ambient noise levels (dBA) in the call centre environment measured in the morning and afternoon over a five-day period.

was 85,3 dBA - significantly higher than the average ambient noise levels obtained in the call centre environment by [11], which were between 54 and 60 dBA.

The most important factor which contributed to the high noise levels was the music in the call centre. The volume of the music was increased through the course of the day to maintain the productivity level of the operators. High ambient noise levels measured in the afternoons (94.0 and 93.8 dBA) were attributed to loud music in the call centre environment. Prolonged exposure to noise levels of 80 dBA or higher may result in hearing loss [12].

A research study on the various aspects of auditory fatigue caused by listening to loud music, especially pop and rock genres, has found that listening to music at an intensity of 80 to 93 dBA may result in a TTS of up to 9.5 dB at 1 000 Hz and a TTS of up to 30 dB at higher frequencies after two hours of exposure [12]. The TTS affected the perception of auditory signals which included temporal and frequency resolution of signals as well as loudness perception. The same study found that listening to music while performing challenging mental tasks results in earlier reports of exhaustion and decreased accuracy in task performance [12].

Discussion

The main objective of this research study was to determine whether extended high-frequency smartphone audiometry may be used as an early indicator of auditory fatigue in call centre operators. Prolonged exposure to noise results in glutamate excitotoxicity which contributes to peripheral auditory fatigue [3]. Changes in hearing due to noise may first be perceived as auditory fatigue, but due to its progressive nature, it is later identified as a permanent threshold shift (PTS) [3]. Study findings demonstrated post-shift threshold shifts which may be attributed to auditory fatigue, with the most statistically significant differences at 500 to 4 000 Hz (bilaterally), 6 000 Hz (left ear), 10 000 Hz (left ear), and 12 500 to 16 000 Hz (bilaterally).

Music at increased intensity levels in the call centre environment may have had an influence on the conventional-frequency and EHF smartphone audiometry results, as indicated by the research [13].

Safety and Health (NIOSH) [14] describes an TTS as a 15 dB increase in hearing thresholds at 500 Hz, 1 000 Hz, 2 000 Hz, 3 000 Hz, 4 000 Hz, or 6 000 Hz, confirmed by two audiometric assessments.

Recovery time varies among individuals and may be affected by individual susceptibility to noise and the type, intensity, and duration of exposure [15]. Individual factors which may prolong recovery time include rest after exposure, age, sex, smoking, high blood pressure, diabetes, genetic predisposition, and level of hearing loss prior to noise exposure [5].

Recurrent exposure to noise levels followed by TTS may result in PTS, as in the case of noise-induced hearing loss (NIHL) [15]. Call centre operators are an at-risk population for this phenomenon. Conventional audiometry and smartphone audiometry were conducted on 100 ears during this study. TTS patterns between 5 to 10 dB were evident at 500 Hz (initial ax: 59 ears; re-ax: 63 ears), 1 000 Hz (initial ax: 37 ears; re-ax: 42 ears), 3 000 Hz (initial ax: 28 ears; re-ax 27 ears), 12 500 Hz (initial ax: 25 ears; re-ax: 27 ears), and 16 000 Hz (initial ax: 29 ears; re-ax: 34 ears). This may indicate that auditory fatigue has a temporary influence on the hearing of call centre operators after an eight- hour shift.

Ear-related complaints such as aural fullness and otalgia, tinnitus, and sensitivity to loud noises reported in the questionnaire are indicators of TTS that may be ascribed to auditory fatigue.

Noise levels were measured over five days and ranged, on average, between 64 and 85.3 dBA, which is considerably higher than the recommended 65 dBA for an appropriate working environment. Call centre operators increase the volume on their headsets when environmental noise exceeds the prescribed intensity to improve the speech intelligibility of the message they receive through the headset [3]. This may then increase susceptibility to auditory fatigue and TTS.

Conclusion

Baseline audiometric assessment indicated that all participants had normal hearing but, despite their young age (19 to 30 years), many reported hearing-related symptoms associated with NIHL.

Initial and re-assessment conventional and smartphone audiometry indicated minor threshold shifts after an eight-hour shift, which may be attributed to the effect of auditory fatigue. Frequencies (500 Hz, 1 000 Hz, 3 000 Hz, 12 500 Hz, and 16 000 Hz) were affected by slight threshold shifts ranging between 5 and 15 dB and rarely exceeding 20 dB.

It was found that participants who presented with increased hearing thresholds atthe initial assessment (15 to 25 dB HL) were more susceptible to a shift in hearing thresholds measured at the post-shift assessment. Elevated hearing thresholds and greater, more frequent threshold shifts at 500 Hz and 1 000 Hz in the absence of a middle ear pathology was a significant finding in this research study.

TTS at 1 000 Hz may be a result of the music played in the call centre at increased intensity levels and it also may have contributed to the threshold shifts in the higher frequencies [13]. Threshold shifts at 3 000 Hz, 12 500 Hz, and 16 000 Hz identified during the post-shift assessment were explained by continuous, moderate ambient noise levels and auditory stimuli presented directly into the ear for a lengthy period, as 74% of operators use the telephone for six hours or longer per day with minimal and short breaks in-between.

The call centre environment and the employees within that environment are a growing point of interest in the field of audiology. Although the noise levels these individuals are exposed to pose a smaller risk for damage than noise levels in industrial settings, it should not be underestimated. It was indicated that long periods of telephone use in an environment with elevated ambient noise levels may result in temporary threshold shifts of up to 20 dB and ear related complaints associated with NIHL.

Bibliography

1. Keeble J. “SA Commercial” (2014).
2. Holman D., *et al*. “The Global Call Centre Report: International Perpectives on Management and Employment”. New York: Global Call Center Network (2007).
3. Venet T., *et al*. “Auditory fatigue among call dispatchers working with headsets”. *International Journal of Occupational Medicine and Environmental Health* (2017): 217-226.
4. Hickox A E and Liberman M C. “Is noise-induced cochlear neuropathy key to the generation of tinnitus or hyperacusis?” *Journal of Neurophysiology* (2014): 552-564.
5. Pawlaczyk-Luszczynska M., *et al*. “Noise exposure and hearing status among call center operators”. *Noise and Health* (2018): 178-188.
6. Antonioli S A., *et al*. “High-frequency audiometry hearing on monitoring of individuals exposed to occupational noise: A systematic review”. *International Archives of Otorhinolaryngology* (2016): 281-289.
7. Rodríguez Valiente A., *et al*. “Earphones in extended high-frequency audiometry and ISO”. *International Journal of Audiology* (2014): 595-603.
8. Stach B. “Clinical audiology: An introduction”. Detroit: Delmar: Cengage Learning (2010).
9. Salkind N. “Encyclopedia of Research Design”. SAGE Publishing (2010).
10. Cicchetti D. “Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology”. *Psychological Assessment* (1994): 284.
11. Smagowska, B. “Noise at workplaces in the call centre”. *Archives of Acoustics* (2010): 253-264.
12. Verbeek J., *et al*. “Interventions to prevent occupational noise-indiced hearing loss: A systematic review”. *International Journal of Audiology* (2014): 84-96.
13. Dobrucki A., *et al*. “Various aspects of auditory fatigue caused by listening to loud music”. In S. Hatzopoulos, Advances in Clinical Audiology. Italy: University of Ferrara (2014): 167-185.

14. “Commission for Occupational Safety and Health” (2005).

15. Ryan A F., *et al*. “Temporary and permanent threhold shifts: A review of basic and clinical observations”. *Otology and Neurotology* (2016): 271-275.