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AUDITORY FATIGUE AMONG CALL DISPATCHERS WORKING WITH HEADSETS

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Abstract
Objectives: To determine whether call center dispatchers wearing headsets are subject to auditory fatigue at the end of a work shift. **Material and Methods:** Data was gathered at times when call centers were busiest. All call operators wore a headset for up to 12 h. Acoustic environment and noise exposure under the headset were continuously recorded during the entire work shift. Variations in auditory parameters were assessed using pure-tone air-conduction audiometry and an objective test based on distortion product otoacoustic emissions – contralateral suppression of distortion product otoacoustic emission (DPOAE) amplitudes (EchoScan test). Thirty-nine operators and 16 controls, all volunteers, were selected from 3 call centers (sales, assistance, and emergency) where all cognitive tasks were accomplished by phone and on computers. **Results:** No acoustic shock was detected during the investigation. The highest normalized noise exposure (daily noise exposure level – $L_{EX,8\,h}$) measured was 75.5 dBA. No significant variation in auditory performances was detected with either pure-tone air-conduction audiometry or the EchoScan test. Nevertheless, dispatchers expressed a feeling of tiredness. **Conclusions:** For an equivalent diffuse field noise exposure, the use of a headset does not seem to worsen auditory fatigue for call center operators. The dispatcher's fatigue was probably due to the duration of the work shift or to the tasks they performed rather than to the noise exposure under a headset. Int J Occup Med Environ Health 2018;31(2):217–226

Key words:
Risk assessment, Noise, Auditory fatigue, Headset, Call center, EchoScan

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INTRODUCTION

In France, occupational physicians have expressed major concerns about call operators' hearing acuity. Part of this concern is due to reports that considerable acoustic levels may be recorded under headsets [1]. Acoustic shocks received through headsets could, naturally, be a source of cochlear trauma [2,3]. In addition, Trompette and Chatillon [1] found that up to 12% of equivalent diffuse field levels exceeded 80 dBA, with maximum levels of up to 90 dBA.

Most operators in traditional and emergency call centers work with a headset in open spaces. These conditions mean that operators are exposed to environmental noise in addition to the communications received through their headsets. The ambient noise on the platform is naturally of a much lower intensity than the noise emitted through the headset, and could be even negligible in terms of overall noise exposure. However, the ambient noise may affect the intelligibility of incoming messages, causing operators to adjust the volume settings on their headset in an attempt to improve the signal-to-noise ratio. The greater the ambient noise, the more the operator should increase the volume on the headset [1,4]. Therefore, the ambient noise may indirectly modify the overall noise exposure.

Noise-induced hearing loss (NIHL) is associated with a number of risk factors related to the intensity and duration of noise exposure. The Occupational Safety and Health Administration (OSHA) in the United States [5], and European legislation [6] require workers whose 8-h average daily exposure exceeds 85 dBA and 80 dBA, respectively, to be enrolled in a hearing conservation program. However, in the context studied here, although exposure may last for a long period, operators are rarely exposed to high noise levels, apart from cases of acoustic shock. It is important to keep in mind that the purpose of this study has not been to investigate the effect of acoustic shocks, but rather to assess potential auditory fatigue due to the long duration of exposure.

Occupational hearing loss is defined as a hearing deficit caused by work-related irreversible cochlear dysfunction whereas auditory fatigue is a more subtle concept. First of all, auditory fatigue must be temporary, that is a required condition. Auditory fatigue is due to 2 main phenomena located at the level of the peripheral receptor. Liberman and Dodds [7] showed that the rootlets of the stereocilia are shortened after moderate-noise exposures, given more flexibility to the structures. Moreover, we all know the swellings underneath the inner hair cells because of a massive release of glutamate within the synaptic cleft. Both mechanisms contribute to the establishment of a peripheral auditory fatigue.

For this study, ambient noise and the noise at workstations were recorded throughout the work shift, and operators' hearing was verified using 2 different approaches. Subjective audiometric thresholds were determined by pure-tone air-conduction audiometry (PTA), which is the current internationally-recognized reference screening tool to assess NIHL. This technique relies on individuals' ability to determine thresholds of hearing sensations related to frequency-specific acoustic stimuli. Thus, in PTA, the central auditory system analyzes each piece of information coming from the peripheral auditory receptor, and could correct for subtle ear dysfunctions or metabolic fatigue to ensure the highest possible level of performance [8–10]. Due to these retro-cochlear compensatory mechanisms, PTA results may underestimate NIHL.

For this reason, we also used an objective test for measuring auditory fatigue. In this test, acoustic stimulation of the efferent reflexes (ER) is used alongside measurement of the distortion product otoacoustic emissions. The recently developed EchoScan [11] device was chosen as appropriate for these types of measurement. As EchoScan elicits the trigger of the efferent reflex, which is defined as the sum of the effects provoked by the stapedial and olivo-cochlear reflexes, the data obtained is not influenced by retro-cochlear compensatory mechanisms, thus making the test more objective and sensitive than PTA. Indeed, the threshold of the ER trigger is very sensitive to auditory fatigue due to noise [11].

Call center operators often complain about auditory fatigue at the end of their work shift, and that was the case too during this study, but the factors contributing to this fatigue have yet to be objectively studied. So, it was relevant to evaluate the auditory fatigue suffered by the operators at the end of their work shift. The main goal of this pilot study was to determine whether call dispatchers present evidence of peripheral (EchoScan) and/or central auditory fatigue (PTA) at the end of a work shift.

MATERIAL AND METHODS

Cohort

The cohort for this study consisted of 55 operators between the age of 19 and 56 years old. Subjects were recruited from hotline call handlers at a French telecom provider (N = 37), the emergency medical call center at a hospital (N = 14), and a technical hotline center (N = 4). The study protocol was approved by the national ethics committee (CPP 2014-A01904-43, authorization code PSS-2014/ECHOSAM-PARIETTI/MS). All volunteers gave written consents for participation in this study prior to determining their eligibility.

Medical and acoustic histories were gathered for all participants in a confidential medical file, and an occupational physician or an ear-nose-throat physician examined each of the participants within the 15 days prior to tests. The exclusion criteria, were, possible ear infection, impacted cerumen, or abnormalities in the external auditory canal as detected by means of otoscopic examination; auditory disease within the past 5 years or use of medical treatment which might affect hearing performance (diuretics, muscle relaxants, aspirin, antibiotics, etc.).

The final cohort was divided into 2 groups: a group of 39 operators working with a headset in a call center, and a control group of 16 participants who performed administrative or management tasks. The average age of the operators was 35.5 years old whereas it was 41.5 for the controls.

Control noise exposure

The volunteers were fitted with noise dosimeters (ACOEM WED) conforming to the American National Standards Institute (ANSI S1.25) [12] and to the International Electrotechnical Commission (IEC 61252) [13]. They wore the dosimeter throughout their working day on the shoulder, and the data it recorded was used for determining the noise exposure level to which each individual was exposed to during their work shift. Dosimeters were controlled with the following parameters: 94 dB at 1000 Hz before starting the measurements.

A 1-second time integration was used for recording the A-weighted equivalent sound level (L_{Aeq}), C-weighted equivalent sound level (L_{Ceq}) and C-weighted peak sound pressure level ($L_{p,Cpeak}$). The daily noise exposure for the 8-h reference period was calculated with a 3 dB exchange rate:

$$10 \times \log(t/8) \quad (1)$$

where:

t – equal to the time measurement in hour.

Operator noise exposure

Noise exposure measurements were performed at the busiest times for each of the call centers; thus, for the telecom provider and in the technical hotline call centers, data was gathered from Monday to Friday whereas in the emergency call center, data was collected during weekends. In the medical emergency call center, the audio volume could be adjusted up to 15 dB in 1.5-dB steps whereas it could be adjusted up to 20 dB in the other call centers.

All operators used a digital amplifier-limiter placed between the telephone and the headset or built into the headset base. Some dispatchers were in the habit of working with a high volume within the headset whereas others used a more moderate volume. During the study, no specific instructions were given to dispatchers as to the sound setting to use. The noise exposure procedure was designed to analyze the operators' occupational conditions, whatever the group to which they were assigned.

The standardized measurement method developed by Trompette and Chatillon [1] was used for assessing the noise exposure level and comparing it to the regulatory 8-h limit. Noise levels under headsets were measured as recommended in the International Organization for Standardization – ISO 11904-2:2004 (Acoustics – Determination of sound emission from sound sources placed close to the ear – Part 2: Technique using a manikin) [14]. This method required the use of an artificial head fitted with an occluded-ear simulator conforming to the specifications described in the International Electrotechnical Commission – IEC 60711:1981 (Occluded-ear simulator for the measurement of earphones coupled to the ear by ear inserts) [15].

For each measured operator, the amplitude transfer function of the artificial head was used for converting the noise spectrum measured by the ear simulator into an equivalent diffuse field level. This provided us with the level of the diffuse field corresponding to the noise level measured within the occluded-ear simulator, and all noise levels could thus be reported as equivalent diffuse noise levels. Due to the spectral composition delivered by the headset type used and the tones of the voices transmitted, the noise level measured by the occluded-ear simulator was on average 7 dBA higher than the equivalent diffuse noise level. The third octave band noise levels received through the headset were recorded during the work shift for each dispatcher. These measurements were then used for determining the equivalent diffuse noise level during conversations, how long conversations lasted, and the equivalent noise exposure for the 8-h reference duration.

The total noise exposure was calculated by adding the conversation noise to the ambient noise, as measured with a 01dB Black Solo® sound-level meter. The ambient noise was negligible in terms of overall noise exposure, unless noise exposure under the headset was less than 66 dBA.

Pure-tone air-conduction audiometry

Pure-tone air-conduction audiometry was performed in a sound-isolated audiometric cabin using an Interacoustics AS608 audiometer with a THD39 headphone equipped with Peltor H7A ear-muffs. The audiometer was calibrated according to the procedure described in EN 60645-1/AINSI S3.6 type 4. Ascending method with 5 dB step was used. During the inclusion procedure PTA allowed to verify that the subjects' hearing was correct between 250 Hz and 8000 Hz.

Based on the results of this first audiogram, only participants with a PTA value below 40 dB HL at 4000 Hz were selected. Indeed, an auditory threshold higher than 40 dB HL at 4000 Hz is often linked to a low amplitude distortion product otoacoustic emission (DPOAEs). As a result, EchoScan could not be used for a reliable measurement. All 39 dispatchers and 16 controls were then tested by PTA prior to and after their work shift to determine work-related alterations.

EchoScan test

As for PTA, all 55 volunteers were tested with EchoScan. Full details on the system may be found in Venet et al. [16]. Briefly, DPOAEs generated by the cochlea [17] were measured in the ipsilateral ear by a probe (Etymotic Research ER10C) with (f1, f2) primaries at (4000 Hz, 4800 Hz), these measurements were used for establishing an input/output (I/O) curve. The linear part of the intensity-magnitude relationship for each subject was determined to further assess the influence of the ER. The intensities of the primaries were always chosen in the linear part of the I/O curve so as to obtain approx. 10-dB sound pressure level (SPL) DPOAE amplitudes.

Contralateral acoustic stimulation was delivered through an earphone (Etymotic Research ER4 B) placed in the outer ear canal. The contralateral noise was an 800-Hz band noise centered at 1000 Hz, 2000 Hz or 4000 Hz. Sound bursts were synthesized by a Bruël & Kjäer Pulse 3160, and lasted up to 2 s at intensities ranging from 65 dB to 95 dB HL. Distortion product otoacoustic emission data obtained without contralateral stimulation were compared to data obtained with contralateral stimulation based on a Student's t-test. The threshold for significance was set at $p < 0.05$ to determine the ER threshold. EchoScan measurements were performed at the beginning and at the end of the work shift, just after the PTA. Because both ears were involved, an audiometric cabin was unnecessary for these tests; a quiet room with a background noise inferior to 40 dBA, such as a professional infirmary, was sufficient.

Statistical analysis

A standard t-test was used for analyzing the between-group (operators vs. control) effect. Before starting work, the variables were PTA level or ER thresholds obtained for each frequency tested. At the end of the work shift, the variables were the variations in the PTA or ER threshold for each frequency:

$$\Delta PTA = PTA_{after} - PTA_{before} \quad (2)$$

where:

ΔPTA – pure-tone air-conduction audiometry (PTA) shifts,

PTA_{after} – PTA thresholds obtained after the work shift,

PTA_{before} – PTA thresholds obtained before the work shift,

or

$$\Delta ER = ER_{after} - ER_{before} \quad (3)$$

where:

ΔER – efferent reflex thresholds,

ER_{after} – efferent reflex thresholds measured after work,

ER_{before} – efferent reflex thresholds measured before work.

The threshold for significance was set at $p < 0.05$.

The standard deviation, σ, is indicated throughout to allow readers to assess the variability of data distribution, and thus to determine how meaningful values are.

RESULTS

Sound exposure received through headsets

The averaged acoustic data recorded under headsets and overall noise exposure levels are reported in the Table 1 which lists the following characteristics: sound level during conversations, call durations, 8-h equivalent noise exposure due to communications, and overall daily exposure (communication plus ambient noise, 8-h reference period).

The mean (N = 39) daily overall noise exposure for operators was low (mean (M) ± standard deviation (SD) = 65.7±3.6 dBA). The distribution and duration of conversations was quite variable, but results showed that sound exposure was mainly determined by the volume setting selected by dispatchers for their headset. Indeed, operators were free to adjust the volume delivered through their headsets to compensate the variability of the acoustic quality receptions or the ambient noise level in the open space.

As mentioned above, overall noise exposure was mainly due to the communications received through headsets. Thus, the mean overall noise exposure of 65.7 dBA was mainly composed of the mean 8-h communication exposure (65.5 dBA); the difference was negligible. Even for the dispatcher with the lowest exposure through their headset (59.4 dBA), the ambient noise level in the call center contributed only to a minor extent to his overall daily noise exposure (61 dBA). Nevertheless, it is

Table 1. Respondents' characteristics in the study of auditory fatigue of call center dispatchers (working with headsets) at the end of a work shift

Study group	Parameter (M±SD)				
	respondent's age [years]	equivalent diffuse field communication sound level [dBA]	call duration (total) [h:min]	equivalent 8-h communication exposure [dBA]	overall $L_{EX,8\,h}$* [dBA]
Operator group – working with a headset (N = 39)	35.6±8.2	69.6±3.7	3:12±1:14	65.5±3.8	65.7±3.6
technical hotline (N = 4)	34.0±4.5	67.3±0.9	4:10±0:23	64.5±0.6	64.5±0.6
telecom provider (N = 21)	36.8±8.3	68.9±3.5	2:37±0:43	63.9±3.2	64.2±3.0
emergency medical call center (N = 14)	34.3±8.9	71.3±4.0	4:12±1:21	68.2±3.7	68.4±3.5
Control group – administrative or management tasks, telecom provider (N = 16)	41.4±4.5	n.a.	n.a.	n.a.	65.3±5.5

M – mean; SD – standard deviation; $L_{EX,8\,h}$ – daily noise exposure level normalized for an equivalent 8-h exposure duration.
* Communication plus ambient noise.
n.a. – not applicable.

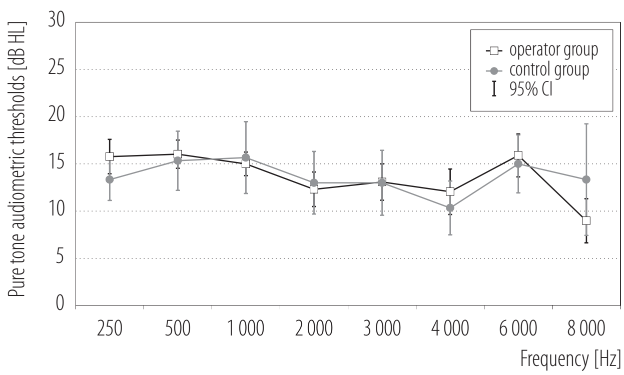
important to keep in mind that the ambient noise level did influence the headset volume chosen by operators, and therefore indirectly affected the overall daily noise exposure.

The mean daily noise exposure for the control group (N = 16) was 65.3±5.5 dBA. Thus, exposure levels were similar for the 2 groups (operator vs. control).

Pure-tone audiometry

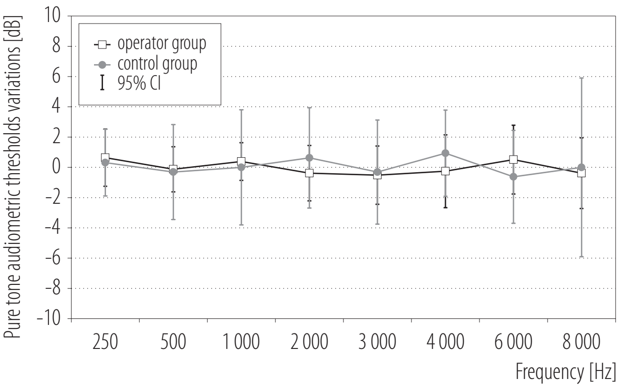
Before starting work, hearing levels were similar between control and operator groups at any of the frequencies tested (Figure 1). A difference was visible at 8 kHz, but it was not significant (p = 0.11), and may probably be explained by the onset of presbycusis in the older control group (mean age of operators was 35.5 vs. 41.5 for controls). Despite these differences, the 2 populations were homogenous enough to make the results relevant.

The PTA shifts (ΔPTA), i.e., the difference in PTA thresholds obtained after and before the work shift (equation 2), are illustrated as a function of frequency in the Figure 2. For the 2 groups, ΔPTA was close to 0 at all frequencies tested. Even for the 7 operators for whom noise exposure was equal to or greater than 70 dBA, ΔPTA were far from being significant at any frequency.



CI – confidence interval.
Operator group (N = 39) – respondents working with a headset in a call center.
Control group (N = 16) – respondents with administrative or management tasks.
Measurements were performed for both study groups prior to exposure, i.e., prior to commencing work.

Fig. 1. Pure-tone air-conduction hearing thresholds in the study of auditory fatigue of call center dispatchers (working with headsets) at the end of a work shift

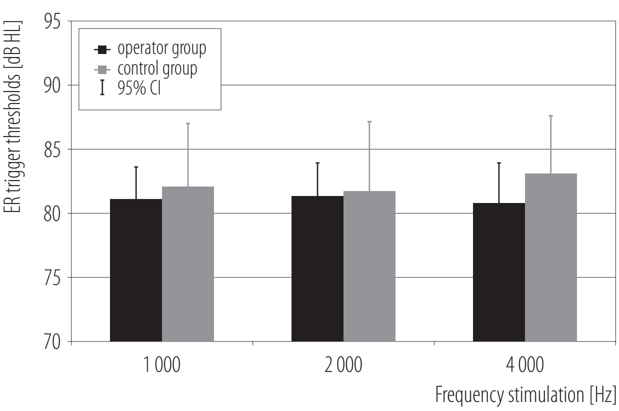


For both study groups the variations were calculated by subtracting values determined before a working day from values determined after completing a work shift.
Other explanations as in Figure 1.

Fig. 2. Variations in pure-tone air-conduction hearing thresholds after vs. before a work shift in the study of auditory fatigue of call center dispatchers (working with headsets)

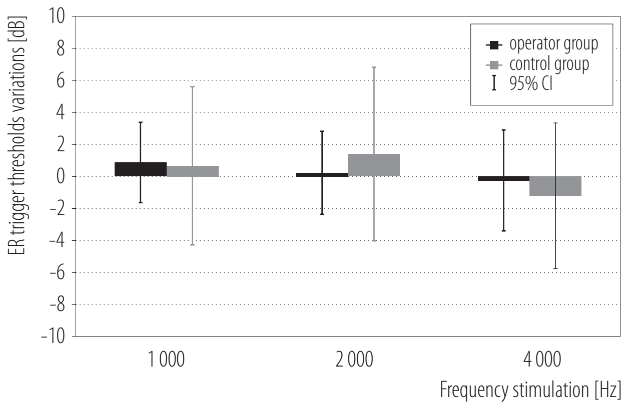
EchoScan

Before starting work the ER thresholds showed no difference between groups, whatever the frequency tested (Figure 3). A relative difference (2.3 dB) was obtained



Distortion product otoacoustic emissions were measured in the ipsilateral ear whereas the suppression noise was delivered through the contralateral ear. Measurements for both study groups were performed prior to exposure, i.e., before starting work.
Other explanations as in Figure 1.

Fig. 3. Efferent reflex (ER) trigger thresholds at 1000 Hz, 2000 Hz and 4000 Hz in the study of auditory fatigue of call center dispatchers (working with headsets)



Distortion product otoacoustic emissions were measured in the ipsilateral ear, the suppression noise was delivered through the contralateral ear. Variations were calculated by subtracting values determined before a working day from values determined after completing a work shift.
Other explanations as in Figure 1.

Fig. 4. Variation in efferent reflex (ER) trigger thresholds at 1000 Hz, 2000 Hz and 4000 Hz in the study of auditory fatigue of call center dispatchers (working with headsets)

at 4 kHz but it was far from being significant ($p = 0.43$). Thus, based on this test too, the 2 groups were homogenous before starting the investigations.

Figure 4 shows the small variations in ER thresholds measured before and after work (equation 3) at the 3 frequencies tested. For the operator group, the differences were 0.9 dB, 0.2 dB, and –0.3 dB at 1000 Hz, 2000 Hz and 4000 Hz, respectively. These differences were not statistically significant at any of the frequencies tested. Even for the 7 operators for whom noise exposure was equal to or greater than 70 dBA, ΔER were close to 0.

DISCUSSION

This study examined peripheral and central auditory fatigue based on 2 complementary hearing tests (PTA and EchoScan). No significant difference in PTA results was found between data collected before and after a work shift in call centers (Figure 2). Even for call center dispatchers exposed to between 70 dBA and 73.5 dBA under the headset, audiograms were as good at the end of the investigation as they were at the beginning. Thus, hearing performance appears to be preserved, and no obvious auditory fatigue was detected using pure-tone audiometry (PTA).

As PTA corresponds to hearing sensations it may be used for evaluating concurrently both peripheral and central auditory fatigues. However, the central auditory system is known to be able to counterbalance slight inner-ear dysfunctions [8–10]. This was particularly well demonstrated by Atchariyasathian et al. [18] who studied hearing performance for 32 noise-exposed workers using both PTA and DPOAEs. While they found no significant difference between exposed and control groups based on PTA results, a decrease in DPOAE amplitudes at 4000 Hz and 6000 Hz was detected.

In our investigation, the plasticity of the central auditory system could also have masked some degree of cochlear defects due to peripheral auditory fatigue, making them undetectable by PTA. To determine whether this was the case, we also used an EchoScan test for assessing peripheral cochlear dysfunction. Like the PTA, this test revealed no significant difference in the ER thresholds. The neuronal circuit triggered by EchoScan to measure the ER threshold implements the physiological function of inner hair cells, afferent fibers, the olivocochlear complex, the efferent fibers, and the middle-ear muscles.

All these elements, except perhaps for the nuclei of the olivocochlear complex, may be considered to make up the peripheral receptor. Because of the neuronal structure of the ER, its trigger, and therefore the EchoScan results, are not influenced by upper central stages (dorsal cochlear nucleus and inferior colliculus). EchoScan measurements may therefore detect peripheral auditory fatigue with a high sensitivity [11] but nevertheless only small and insignificant variations in ER thresholds were measured in the cohort tested here.

Thus, like for the PTA results (Figure 2), no significant difference in ER thresholds was found (Figure 4). Based on these results, we are confident in asserting that our cohort of operators from 3 different call centers have not experienced either central or peripheral auditory fatigue.

These findings are not all that surprising since the mean 8-h noise equivalent exposure received through the headset (65.7 dBA) was considerably lower than the noise levels commonly recorded in factories. This noise level was also well below the first action level defined in European directive 2003/10/EC [6] (80 dBA) or the OSHA's action level [5], 85 dBA. In fact, the average of the 8-h noise exposure measured in the operator group (65.7 dBA) was equivalent to the noise exposure recorded for people dealing with administrative tasks belonging to the control group (65.3 dBA).

Despite these findings, the population of dispatchers reported a sensation of fatigue, and a number of operators suffered from a feeling of auditory fatigue. In the occupational conditions of a call center, this perceived fatigue could be related to cognitive fatigue or emotional exhaustion, due to the heavy mental workload, and to call center specific stressors [19,20].

In all the call centers investigated, the operators managed incoming and outgoing calls and performed other tasks in the meantime. For instance, they entered data into their computers, processed creation files, sought solutions within a short time-frame. Sometimes the conversations were conflicting or highly emotionally charged, requiring urgent reactions from the operators, possibly hinging on life/death decisions. All these factors may be sources of stress and therefore potentially increase fatigue. In such conditions, the noise level under the headset, which is a characteristic of this type of work may be experienced as the main source of strain at the work station, leading to significant levels of perceived auditory fatigue for operators.

Other tools would be required to estimate the emotional dimension of the job performed by call dispatchers and how it impacts perceived fatigue.

CONCLUSIONS

In the occupational conditions tested in this study, mid-level background noise and an appropriate hardware configuration (a headset equipped with electronic limiter, no acoustic shock), the daily noise exposure did not cause any detectable central or peripheral auditory fatigue. For dispatchers working with headsets, the sensation of auditory fatigue could be caused by a cognitive fatigue.

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