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Model of Interactive System for Training in the Proper Use of Hearing Protection Devices

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In 2011, over 520 thousand persons worked in hazardous conditions (according to the GUS). Among hazardous factors related to working environment noise was found to be the most common one, threatening 199,6 thousand people (52.9% threats-per-persons related to working environment). The prevalence of workplace noise and increasing awareness of effects of its impact on the human body causes increase of the demand for knowledge of the methods of noise reduction. Due to the lack of knowledge concerning the proper use of hearing protectors, effective noise exposure in the real world may be about a dozen dB higher than the declared assumed protection value. For this reason, in Central Institute for Labour Protection – NRI "The interactive system for learning the correct use of hearing protectors" has been developed. The system includes a multimedia guide on hearing protectors supplemented by video tutorials, training materials with training hearing protectors, and software for evaluation of the activities of the trainee.

Keywords: active noise reduction, hearing protectors.

1. Introduction

Noise in the work environment is the most commonly occurring harmful factor. Over 199,000 people in Poland work in hazardous conditions, which accounts for 52.9% of all threats-per-persons related to working environment (according to the Central Statistical Office data for 2011) (GUS, 2012). Inspections conducted at workplaces by the National Labour Inspectorate, the results of which are presented in the report of the Chief Labour Inspector on the activity of the National Labour Inspectorate in 2010 (PIP, 2012), revealed that in 22% of cases incorrect personal protection equipment (including hearing protection devices) had been selected. Results of the tests (Murphy, Franks, 2000; Stevenson, Teare, 2004; Młyński, Kozłowski, 2013; Pawełczyk, 2010) concerning effective protection against noise provided by hearing protection devices have shown that real-world attenuation (when hearing protection devices are worn by workers) is sometimes lower, by as much as several decibels, than the declared assumed protection value (APV – sound attenuation measured in laboratories for certification purposes).

During the tests carried out by CIOP-PIB (Kozłowski, Kotarbińska, 2007) it was found that in about 53% of cases the real-world attenuation provided by hearing protection devices (HPDs) was lower than recommended. This means that in some cases individual exposure to noise could exceed admissible values. It should also be noted that the real-world attenuation provided by hearing protectors is lower when those are used by personnel untrained in the proper use of HPDs (Canetto, 2009). Meanwhile – as evidenced by research – workers are not always appropriately instructed in the use of HPDs (Lusk *et al.*, 1995).

The main causes of improper use of such devices (Fig. 1) include: incorrect assessment of their technical condition (about 34% of cases) and insufficient knowledge on the use and adjustment of those devices (about 15% of cases).

As pointed out in A. Mayer's research (Mayer, 2007), an important factor affecting the differences between the APV and the real-world attenuation is that the assessment of personal protection equipment's (including HPDs) effectiveness is carried out in standardized tests (such as the EC-type examination) in ideal conditions (PN-EN, 1999), which obviously dif-

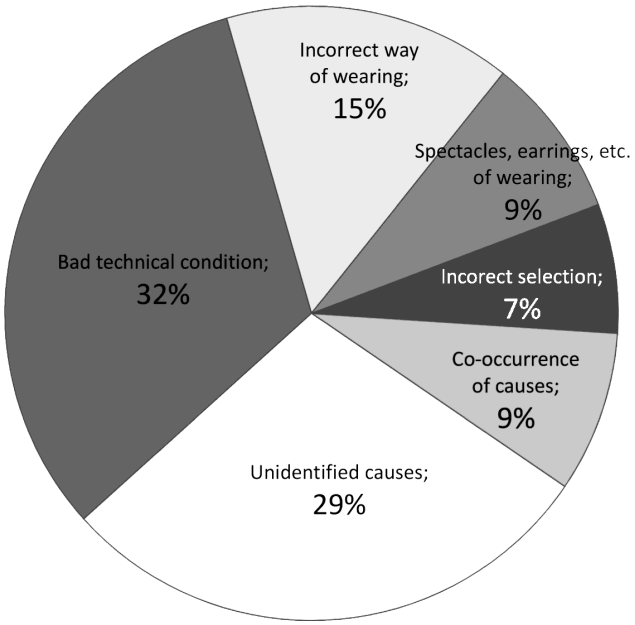

Fig. 1. Causes of lower real-world attenuation of hearing protection devices (according to the tests by CIOP-PIB (Kotarbińska, Kozłowski, 2009)).

fer from real-life conditions where personal protection equipment is normally used. Standardized test methods adopted and used as a basis for evaluating the effectiveness of personal protection equipment are often simplified. This simplification consists mainly in replacing the personal protection equipment operating conditions by laboratory conditions and is used to obtain repeatable, reproducible, and cost-effective tests.

The reasons discussed above show that an important role in reducing noise exposure is played by educating both the personnel wearing HPDs and health and safety professionals in the correct use of such devices (Morzyński, 2011; Radosz 2012; 2013). Solutions described to date in the international literature concerning the systems for training in the proper use of HPDs (Christian, et al., 1998) do not include interactive components or are limited to specific issues (such as the rolling of earplugs or general information about noise), which – in the light of the tests conducted – should be considered insufficient.

Further in this article a model of an interactive system for training in the proper use of HPDs is presented. The system is designed to provide instruction and facilitate the acquisition of skills by trainees in the proper use of HPDs.

2. Model of a training system for the proper use of hearing protection devices

The correct use of HPDs must be understood *inter alia* as a correct selection of such devices, as well as having the knowledge of how to wear and adjust these devices combined with an ability to assess their technical condition. The idea of the presented system is to introduce, as part of a training programme, tutorial videos demonstrating the proper use of HPDs and the development of teaching aids in the form of training hearing protection devices (t-HPDs) enabling verification of their correct selection and use. The entire training system for the proper use of HPDs includes a number of workstations equipped with t-HPDs (Fig. 2), one of which acts as an HTTP server.

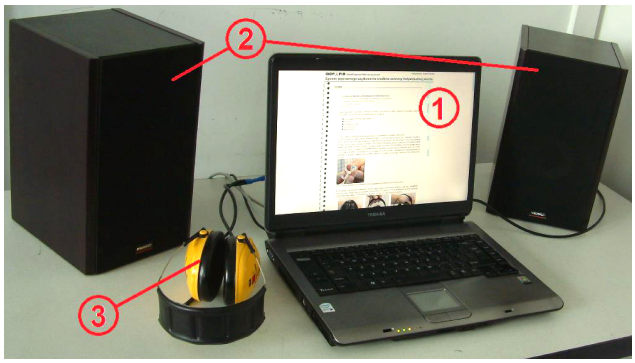

Fig. 2. View of the interactive system for training in the proper use of hearing protection devices (1 – workstation with special software, 2 – test signal sources, 3 – test hearing protection devices).

All workstations are connected to the server via a LAN or WAN, and each of them, once accessed by means of a proper password and access rights, can act as a workstation of the person conducting the training or be used as a workstation for trainees in the use of HPDs. Each workstation consists of a computer equipped with a special software and t-HPDs with test signal sources. Test HPDs are connected to the workstation via USB. A workstation user will use a web browser to access training materials concerning the proper use of HPDs, including a multimedia guide. Users can also carry out exercises to verify their knowledge, which includes the use of the t-HPDs.

The developed t-HPDs consist of test HPDs, a communication module, an application, and test signal sources (Fig. 3). The technical implementation of a workstation equipped with test HPDs consists in fit-

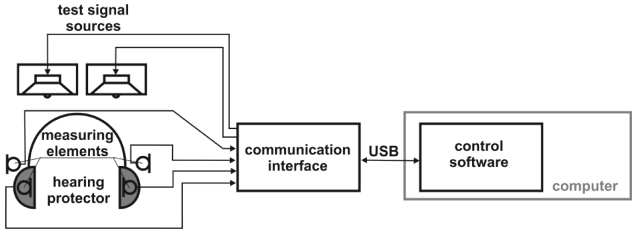

Fig. 3. Diagram of the training in hearing protection devices.

ting selected hearing protector devices generally available in the market (earmuffs and earplugs) with microphones to measure sound pressure levels inside and around the hearing protection device. At the current stage, two options of design solutions relating to the manner of measuring acoustic signals have been developed. The first option concerns the measurement of sound pressure levels inside and around earmuffs by direct measurement, using electret microphones, while the other entails measurement of the sound pressure level inside HPDs using a measurement probe (in this case, the measurement applies to earmuffs and earplugs).

During the training the workstation will emit test signals to measure the actual value of real-word attenuation provided by the HPDs. These measurements are the basis for verifying whether the HPDs are worn correctly. A developed algorithm implemented in the application makes it possible to assess whether a trainee is wearing the HPDs correctly. The results of this assessment will be presented in the workstation screen (Fig. 4).

The displayed application window is divided into four sections. The first three include the steps necessary to carry out measurements. First, the user selects the number of the test hearing protection device for performing the exercises. As soon as the test hearing protection device is selected, a photograph is displayed in the second window and the user's task is to put on the hearing protection device shown in the photograph. After that the trainee starts the measurement procedure of real-word attenuation of the hearing protection device in use. After the measurement of the real-word attenuation of the HPDs is completed, the results are displayed on the screen in the "Assessment of the correct use of the hearing protection device" window. At the same time, the sound attenuation value of the HPDs as declared by the manufacturer is displayed along with the difference between these values. If the measured value is lower than the APV claimed by the manufacturer, it is assumed that the protection device has not been worn correctly. If the difference between the measured values (for the left and right earcups) is greater than the standard deviation claimed by the manufacturer, it is assumed that the protection device has been worn incorrectly as well. This is shown in a schematic drawing by earcup colour changes. The red means "too low attenuation by the protector", green means "correct attenuation", and orange stands for "too high attenuation". Below the earcups, differences between the mean attenuation value and the measured value are displayed. On the right side of the figure a comment on the assessment of the correct use of the hearing protection device is displayed as well as instructions showing suggestions for improvement in its use. After performing the instructions, the trainee restarts the measurement procedure of the real-word attenuation provided by the hearing protection device in use. The procedure is repeated until the desired effect is achieved, or the test protection device is changed.

Fig. 4. View of the application screen following a measurement of real-word attenuation of the training hearing protection devices (only in Polish).

There are three areas of operations in the HPDs training system, depending on the authorizations of the system user (Fig. 5). The first is the area of an anonymous user, the second is that of a registered user, i.e. a trainee, while the third one concerns the administrator, or the person conducting the training. In the system user areas, there are two modules, designed for training and verification of the knowledge about the proper use of HPDs. The module for verifying the knowledge is available only for the registered user.

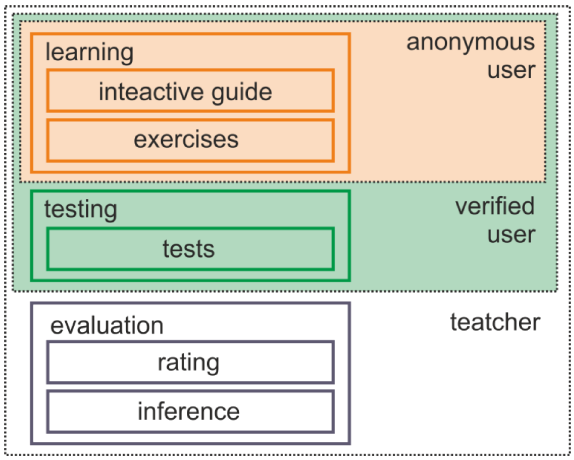

Fig. 5. Functional diagram of the interactive system for training in the proper use of hearing protection devices.

The main component of the module designed to train in the proper use of HPDs is a multimedia guide that allows to acquire knowledge on issues related to the proper use of HPDs. It is supplemented by a number of multimedia items, including tutorial videos and online tools for selection of HPDs. The module instructing in the proper use of HPDs also includes a set of exercises for knowledge verification. It is assumed that during the exercises some questions will require the use of t-HPDs. The system will automatically start the training aid hearing protection device software and conduct the measurement of the real-word attenuation provided by the hearing protection device being worn. Questions are asked in a random order.

Answers to the questions are provided by ticking the check box next to the selected answer (Fig. 6). It is important to remember that there can be more than one correct answer. As soon as the selected choices are verified, the system displays the correct answers. The module that is available only for registered users is the knowledge verification module. At this stage of the training, the users can verify their knowledge in examination tests. These tests are a practical assessment of the skills acquired. A single test consists of a set of 10 questions. As in the case of sets of exercises, answers to questions are provided by ticking the check box next to the selected answer. During the test the selected answer cannot be verified for correctness. Likewise, during examination tests at least one question requires the use of t-HPDs. As in the case of exercises, the system will automatically start the training aid hearing protection device software and measure the real-word attenuation provided by the hearing protection device being worn. After answering all the test questions a summary result of the test is displayed. Test results are stored in a database and available for both the trainee and the trainer. The third system area is the administrator area or the trainer area. A person with access to this area can see the knowledge verification data, including the results of all registered users, and can analyse these results. By analysing the test results, the trainer can assess the progress in the training of individual users during the current training as compared to the previous training sessions.

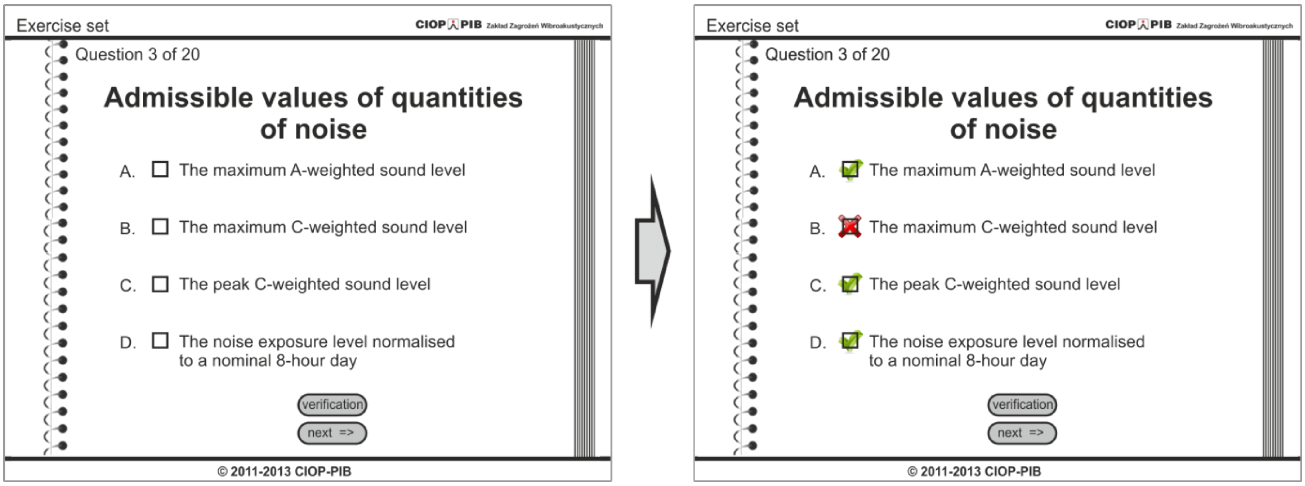

Fig. 6. View of a selected page from an exercise set – before and after answers are verified (only in Polish).

3. Conclusions

The presented model of a system for training in the use of HPDs combines a training programme of tutorial videos demonstrating the proper use of HPDs and training aids in the form of t-HPDs, providing an opportunity to verify their correct use. Those devices connected to a computer running appropriate software can be used to assess, on an on-going basis, the activities of the trainee and display the assessment results on the screen. As stated in the paper, an important part of preventive measures associated with noise pollution in the work environment is to educate both employees wearing HPDs and health and safety professionals in the correct use of HPDs. Effective education will reduce incorrect uses of HPDs, thus reducing personal exposure to noise of the workers using HPDs. Introduction of an interactive training system for a measurable verification of the knowledge acquired during the training in the correct use of HPDs will undoubtedly help to reduce workers' exposure to excessive noise. Introduction of an opportunity for trainee self-assessment during the training, to verify the practical knowledge and skills, is likewise an important fact. Application of the developed solution will enable training companies and OSH departments to conduct more interesting and more effective trainings in the proper use of HPDs.

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