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Noise exposure of employees in retail trade

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Abstract

Noise can lead to extra-aural effects, which can diminish the health of employees in the long term. To protect the employees from extra-aural noise effects, a new national regulation for measurement and rating of noise at workplaces became active in Germany by means of a technical rule. In order to assess the situation of employees in retail trade, measurements of noise exposure were carried out following the mentioned technical rule and ISO 9612. Personal sound exposure meters were used to determine the physical exposure at the ear of employees. Stationary measurements next to the cashiers area were performed additionally. For psychological evaluation of working-condition-perception, a validated questionnaire (BASA II) was used. Furthermore, room acoustic measurements were performed in representative retail stores as well as binaural recordings for psychoacoustic analysis purposes. Outcomes of this project will be presented and discussed for personal and stationary sound pressure levels. Measurement method and rating of results in German legal requirements turned out to be difficult to apply for these types of workplaces, as will be discussed in detail. In addition, the results of the measurements and the questionnaire will be reviewed to show the relationship between perceptual and analytical variables.

Keywords: Noise, Workplace, extra-aural, Retail

1 INTRODUCTION

Employees in retail trade are exposed to different types of sounds in their everyday work. Depending on the activity performed, the auditive input comes from different sound sources like customers talking, children crying and screaming, the own and the tills beeps of the other colleagues and many other different sources. To protect the employees from extra-aural effects, which do not affect aural damages to the inner ear, a new national regulation for measurement and rating of noise at workplaces became active in Germany by means of a technical rule. It is called “Technical Rule for Workplaces ASR A3.7 Noise” (short: ASR A3.7) [1] and is used to protect employees at workplaces with an A-weighted sound pressure level lower than 80 dB. It concretes the minimum requirements according to the German Workplaces Regulation. Measurements and evaluation of sound pressure levels at workplaces above 80 dB are regulated in the “Ordinance on noise and vibrations protection” and the according technical rules (short: TRLV noise) [2]. Those technical rules are connected to the measurement methods described in ISO 9612:2009 [3] evaluating the daily noise exposure level $L_{EX,8h}$ as descriptor for protection of aural health. Sound pressure levels lower then 80 dB were expected in this project in retail trade, but still ISO 9612 is important for this paper, because of different lacks in the measurement method of ASR A3.7.

The aim and motivation for this project is first to capture the exposition of employees in retail trade systematically, especially in textile and food retail. First, there is a huge interest from the occupational safety and health point of view. Despite the changing world of work, noise is one of the most widespread reasons for complaints. Second, since the release of ASR A3.7 media and trade unions demand for better protection of employees in retail trade in Germany.

2 METHOD AND MEASUREMENTS

To capture the noise exposure of employees in retail trade, measurements are performed by the responsible occupational noise measurement service of the German Social Accident Insurance Institution for Trade & Distribution Industry and IFA in the period of time from March to September 2018. Following measurands are determined

- A-weighted sound pressure level at employees ears, measured with personal sound exposure meters,
- A-weighted and A- and impulse-time-weighted sound pressure level in the cashiers area, measured stationary,
- reverberation time in representative retail stores,
- psychological evaluation of working-condition-perception with the help of a validated questionnaire [4].

Additionally binaural recordings are performed in representative retail stores for psychoacoustic analysis purposes. A special focus is set to the first three points of this enumeration. The different methods for determining the above mentioned points are presented subsequent.

2.1 Person-related measurements

Activities carried out by employees in retail trade are rarely stationary, except cashing. Therefore, measurements with personal sound exposure meters are performed. To ensure the correct position of the personal sound exposure meter according to ISO 9612 [3], suspenders are used. The correct position is very important for the determination of the correct sound exposure. With retail sector specific knowledge of the corresponding social accident insurance institution diverse activities are collected into a catalogue: *stocking goods, cashing, storage activities, garbage disposal, breaks, cleaning, sales*. This activity-catalogue helps to observe the employees during the measurements with personal sound exposure meters and is needed for the activity-based evaluation of the measurements. In addition, sound pressure level profile sections can be evaluated considering the relevant activities and not only as a whole job-based measurement. Inherent noise is not excluded from the measurements, as demanded by ASR A3.7 [1], because of manifold reasons: first, a large part of the activities carried out causes inherent noise, like cashing, sales and stocking goods onto their sale-places. Second, the definition of *inherent noise* by ASR A3.7 is not clearly differentiated for those types of workplaces [1]. For that reasons the physical exposure to the employees ears is the result of those measurements.

2.2 Stationary measurements in cashiers area

Stationary measurements are performed in the cashiers area. Therefore, sound level meters are located at non-occupied tills. The measurands are $L_{p\mathrm{AIeq}}$ and $L_{p\mathrm{Aeq}}$.

2.3 Room acoustics measurements

Measurements of reverberation times are conducted in representative retail stores of both branch sectors during the opening hours. Room impulse responses are collected with MLS method (*maximum length sequence*). Reverberation times are calculated from the room impulse responses.

2.4 Binaural recordings

For psychoacoustic analysis purposes binaural recordings with an artificial head are performed in representative retail stores, especially in the cashiers area. Those recordings will also be used for further investigations and listening tests.

2.5 Questionnaire: working-condition-perception of employees

To inspect the employees working-condition-perception, a validated questionnaire is used. BASA II is a screening procedure used for determination of promotional and impairing conditions at work [4]. 16 items are added to the survey to highlight the topic "noise exposure" in more detail. Furthermore, the German short noise-sensitivity questionnaire with nine items is added as well [6]. The questionnaire encompasses 128 items in total. The employees respond anonymously and online using a provided tablet during working time and after the measurements. No personal data is collected.

3 GERMAN NATIONAL REGULATION: ASR A3.7

For presenting the actual stage of this project, an overview of German national regulations is essential. Released in May 2018, during the already ongoing project, the Technical Rules for Workplaces ASR A3.7 "Noise" defines the minimum requirements for protection of employees from extra-aural effects [1]. The requirements are split in two parts: first there is the so called "rating level" L_{r}, which is defined for three different types of activities ("*activity-categories*") and must not be exceeded. Second, there are prescribed reverberation times depending on the room usage.

The "rating level" L_{r} is defined as the A-weighted equivalent sound pressure level with penalties for tonal and information-containing noise (K_{T}) as well as for impulse noise (K_{I}) (Equation 1).

$$L_{\mathrm{r}} = L_{p\mathrm{Aeq}} + K_{\mathrm{I}} + K_{\mathrm{T}} \tag{1}$$

K_{I} is calculated from the difference between the A- and impulse-time-weighted (time-weighting with $\tau_{\uparrow} = 35\,\mathrm{ms}$, $\tau_{\downarrow} = 1500\,\mathrm{ms}$) and A-weighted sound pressure level. This difference is only evaluated and added to $L_{p\mathrm{Aeq}}$ if it is between three and six decibels. Values lower then three are set to zero and values higher then six are set to six decibels (Equation 2).

$$K_{\mathrm{I}} = \begin{cases} 0 & \text{if} \quad (L_{p\mathrm{AIeq}} - L_{p\mathrm{Aeq}}) < 3\,\mathrm{dB} \\ L_{p\mathrm{AIeq}} - L_{p\mathrm{Aeq}} & \text{if} \quad 3\,\mathrm{dB} \leq (L_{p\mathrm{AIeq}} - L_{p\mathrm{Aeq}}) \leq 6\,\mathrm{dB} \\ 6 & \text{if} \quad (L_{p\mathrm{AIeq}} - L_{p\mathrm{Aeq}}) > 6\,\mathrm{dB} \end{cases} \tag{2}$$

The penalty for tonal and information-containing noise K_{T} is evaluated subjectively by the person performing the measurement. It is possible to set the penalty to 3 or 6 dB, dependent on the perceived prominence of the information-containing or tonal noise at the workplaces. The sum of both penalties $K_{\mathrm{I}} + K_{\mathrm{T}}$ is limited to 6 dB.

In ASR A3.7 three categories of activities are mentioned. The activity-category I is characterized as "high concentration or high speech intelligibility", e.g. "making decisions with high impact under time pressure, formulation and/or understanding of complex texts, ...". For this activity-category a rating level of 55 dB must not be exceeded. "Mid concentration or mid speech intelligibility" is demanded for the fields of activities in the category II. The rating level limit is set to 70 dB for activities like "making decisions with low impact and without time pressure, easy to process, recurring tasks, ...". For the activity-category III rating levels must be reduced as far as possible, taking into account noise abatement measures. This category is described as "low concentration or low speech intelligibility" and includes routine and simple work.

The measurement method for evaluation of the rating level relates to DIN 45645-2 [5]. After analysing the fields of activity, which are carried out cumulatively for at least one hour on a representative working day, a measurement of the sound pressure level in the height of the employees ears excluding the inherent noise is necessary. Inherent noise is described as "*noise as a result of conversations with other persons and communication signals assigned to the workstation, e.g. telephone, computer keyboard, ...*". To exclude those inherent signals during a measurement, the measurement has to be interrupted. Otherwise a measurement has to be performed without the employee in question and its communication equipment. The penalties are calculated after the measurement in the way described above. Finally, the rating level can be determined and compared with the

limit value of the corresponding activity-category.

For room acoustics purposes there are reverberation times defined for the octave bands from 250 Hz to 2000 Hz for four different types of room usage (Table 1), which should not be exceeded. Three refer to offices and one to educational institutions. One room usage is referred as "other rooms with usage for communication" with a value of $\bar{\alpha} \geq 0.3$ in the above mentioned frequency range.

Table 1. Reverberation times T in the octave bands from 250 Hz to 2000 Hz for different room types, which should not be exceeded according to ASR A3.7 [1]; with V as room volume in m^3

Room usage	T	tolerance
Call center	0.5	-
Multi-person and open plan office	0.6	-
One- or two-person office	0.8	-
Educational institutions	$(0.32 \cdot \log(V) - 0,17)$ s	$\pm$ 20 %

4 EVALUATION AND RESULTS

4.1 Person-related measurements

Table 2. Overview: number and duration of personal sound exposure meter measurements

Retail sector	Food	Textile
Measurement location	12	4
Number of measurements	26	16
Measurements with activity-based evaluation	15	14
Measurement duration [hh:mm:ss]	53:28:07	33:14:58

In total, approximately 87 hours of measurements with personal sound exposure meters are conducted in textile and food retail. In Table 2 measurement locations, meaning the number of different retail shops, and the over all number of measurements with personal sound exposure meters are shown. An activity-based evaluation is not possible for all measurements performed, because of insufficient logging of activities or because of activity combinations during the measurements.

Table 3. Activity-based measurement results of person-related measurements in **food retail**; arithmetic average L_{Aeq}, standard deviation (SD) $\sigma(L_{\mathrm{Aeq}})$ and measurement duration t

Activity	Arithmetic average [dB]	SD [dB]	t [min]
Stocking goods	72,3	4,0	715,4
Cashing	72,0	4,7	656,8
Storage activities	72,8	4,2	157,6
Garbage disposal	77,0	7,8	21,7
Break	66,5	3,1	126,1
Cleaning	67,1	6,9	7,5
Sales	73,8	7,7	39,9

The activities *cashing* and *stocking goods* have the highest measurement duration independent of branch sector (Tables 3 and 4). Nevertheless, the deviation between the exposure at the employees ears, described by the sound pressure level L_{Aeq} as arithmetic mean for one activity across all stores of one branch sector, is small.

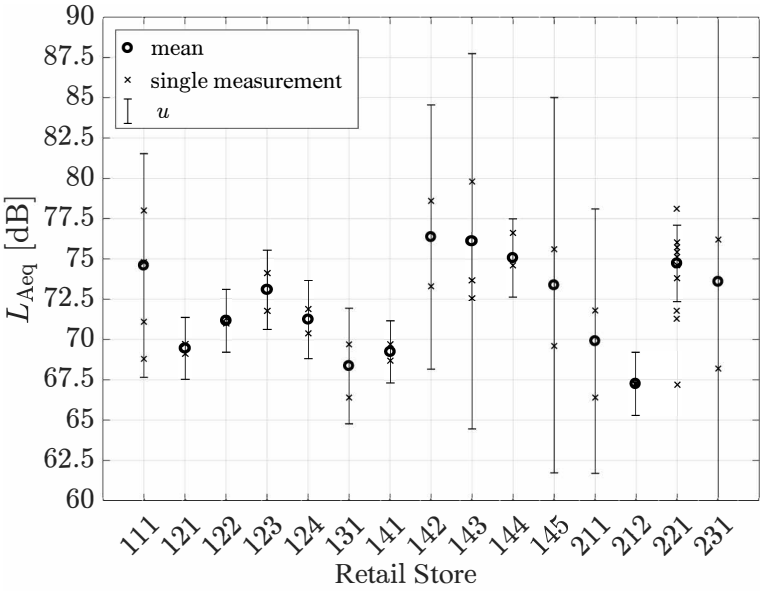

Figure 1. Evaluation of single measurements L_{Aeq} as energy-equivalent mean per retail store (code for anonymity) with combined standard uncertainty u according to [3] and single measurements "×".

Therefore, no differentiation based on activity is possible. On that account an energy-equivalent mean per retail store and the appurtenant combined standard uncertainty according to strategy 2 "job-based measurement" of ISO 9612 is calculated (Figure 1). High combined standard uncertainties are justified by a small amount of single measurements in the particular retail store wit a quiet high deviation from one another.

Table 4. Activity-based measurement results of person-related measurements in **textile retail**; arithmetic average L_{Aeq}, standard deviation (SD) $\sigma(L_{Aeq})$ and measurement duration t

Activity	Arithmetic average [dB]	SD [dB]	t [min]
Stocking goods	72,0	3,6	745,1
Cashing	74,0	1,4	850,8
Storage activities	71,6	3,1	99,0
Sales	71,3	3,1	52,4

4.2 Stationary measurements in cashiers area

The arithmetic average A-weighted sound pressure levels in the cashiers area are 63.8 dB (min: 58.7 dB, max: 67.7 dB) for food and 62.3 dB (min: 57.3 dB, max: 67.9 dB) for textile retail sector. The difference between $L_{AIeq} - L_{Aeq}$ for the evaluation of a possible penalty K_I is higher than 6 dB, independent of the branch sector (Figure 2). For the activity *cashing* a penalty of 6 dB is necessary for calculation of a possible rating level L_r. The noises contributing to the impulse penalty are, among others, the customer conversations, the music and advertising announcements.

4.3 Room acoustics measurements

The determination of the room acoustic parameters during opening hours shows $\bar{\alpha} \geq 0.5$ in all relevant octave bands. Thus the target values according to ASR A3.7 are more than achieved. Those high values can be reached

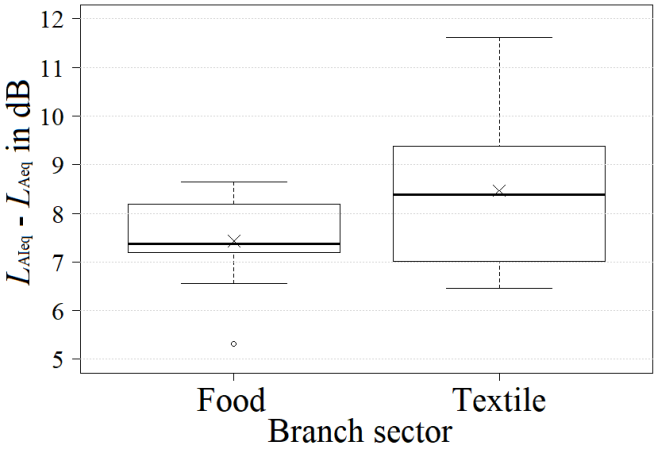

Figure 2. Boxplot: difference between $L_{\mathrm{AIeq}} - L_{\mathrm{Aeq}}$ in cashiers area for stationary measurements with arithmetic average "×" and an outlier "○" from 22 stationary measurements in food and 18 in textile retail.

due to absorptive ceilings in nearly every retail store. Additionally, in textile retail garments have an absorptive effect and in food retail the shelves help to inhibit sound propagation.

5 CONCLUSIONS AND DISCUSSION

The person-related measurement results show, that a differentiation on activity-basis is neither useful nor meaningful. Additionally, the measurement observers could have different interpretations of one and the same situation. A central data analysis of various measurements could also lead to misinterpretations. For example, a sales conversations could be catalogued as *sales* or *stocking goods*, if the employee is stocking goods and helps out a customer to find the product of interest.

Therefore, an evaluation of the results on a retail store basis is more useful and represents the effective, physical exposure at the employees ears in each retail store. The evaluation of the rating level according to ASR A3.7 [1] is questionable, because of the exclusion of the inherent noise. This inherent noise has a high temporal share within the executed activities. It is not only the communication with the customers or colleagues, it is also questionable which sound can be classified as inherent. The tills beeps for example can be apprehended as an acoustic feedback to the employee, but it can also be a stressor. Furthermore, the definition of inherent noise and the measurement method described in ASR A3.7 and DIN 45645-2 do not work for activities in retail trade and is better applicable in office situations [1][5]. Performing measurements in absence of for example an employee at the till is not that easy. The absence of the employee also entails the absence of the customers at the checkout. There is no sound coming from talking customers and unloading the shopping cart on the belt. Those and other difficulties have to be considered.

The stationary measurements show a situation comparable with the one demanded by ASR A3.7 at a non-occupied till. Nevertheless, the measurement conditions can be incomparable among one another, because of different distances to the real workplace and different in-situ setup conditions of the sound level meters. However, the stationary measurements indicate a sound pressure level area from 57 to 68 dB. Calculating a rating level a penalty of 6 dB has to be considered for the activity *cashing*.

Noise abatement using room acoustic measures is not expedient, since nearly all retail stores do have absorptive ceilings and the room acoustic situations are adequate. Other noise abatement measures could also help, like

- insulating mats inside of collecting containers for clothes hangers or anti-theft tags,
- stop dampers for cash drawers,
- no positioning of freezers and bottles-/cans-deposit-machines in immediate proximity to the cashiers area,
- tills beeps can be adjusted in sound pressure level.

In the further project progress the analytical variables will be connected to the perception-based parameters evaluated with the help of the questionnaire. A precise contemplation of the psychoacoustic analysis in combination with the perceptual evaluation will be prepared. The monaural worn headset has also proved to be a challenge for occupational safety and health in the retail trade.

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