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Noise as a cognitive impairment factor: a case study amongst teachers

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ABSTRACT

Noise is widely recognised as one of the most important risk factors in occupational environments, in particular in what concerns the risk of hearing loss development. However, noise exposure may cause also other important effects, namely at a cognitive level. Teaching activities with young students, due to its own nature, can be a very demanding job in what regards cognitive requirements. This study aims at finding out the possible relationship between classroom noise exposure and teachers' cognitive performance. As this relationship will be analysed from the cognitive impairment point of view, it is important to bear in mind also the individual noise sensitivity. Accordingly, this study also includes the application of the Weinstein's Noise Sensitivity Scale (WNS). The study sample includes 16 teachers, which were divided into 2 different groups, one related with practical teaching activities (P) and the other related with theoretical teaching activities (T). Subjects were also divided according to obtained WNS score of each of them, into a Noise Sensitive (NS) and a Non-Noise Sensitive (NNS) groups. Noise exposure was measured in all classrooms considered during four weeks, and the corresponding noise equivalent level was registered. In order to test and register teachers' cognitive performance, all the teachers performed a cognitive test, applied in a personal computer, during four weeks and in two different moments within the same day. The obtained results indicate that, in terms of noise exposure, the highest registered one-hour equivalent levels were 73.0 and 84.3 dB(A), for the P and T groups respectively. The results from the cognitive performance tests show that the P group had a better performance than the TP. However, both groups showed a decrease in their performance after being exposed to classroom noise. When analysing performance in both noise sensitivity groups, it is possible to notice that the NNS group had a better performance, but both groups showed also a decrease in their cognitive performance under the same exposure circumstances. The results showed that there is a statistical significant relationship between noise exposure and cognitive performance for the considered teachers, although this may not occur in all the analysed scenarios. Finally, it is important to mention that these results show the need to consider noise exposure risk in cognitive demanding jobs, such as a teacher job.

INTRODUCTION

Teachers and students are typically exposed to daily noise exposure levels that are likely to influence the teaching-learning process and lead to psychological and physiological effects for both of them. The noise levels that teachers and students are exposed to in the classroom may also become higher due to the use of new teaching equipment and teaching methodologies, applied with the aim of promoting students' participation and the interaction between teachers and students.

If, on the one hand, the typical noise exposure level in classrooms is not high enough to cause clear physiological damage, such as hearing loss, on the other hand, the consequences of this exposure can be reflected in the medium and long-term, leading to extra-auditory effects, for example, other effects at the psychological level. Amongst some of the possible effects of this type of exposure, it is possible to mention the decrease in the concentration level, in the cognitive performance, in memory capacities, etc.

Despite the mentioned effects, the action values defined in the Portuguese legislation (DL 182/2006), namely the lower exposure and upper exposure action values for daily exposure levels ($L_{EX,8h}$), which are 80 and 85 dB(A), respectively. Legislation defined the action values based on the specific risk of hearing loss and, accordingly, it assumes that exposure values below 80 dB(A) do not represent any relevant risk for the exposed workers.

In the literature review it is possible to notice that although many studies recognise that exposure to occupational noise may results in physical and physiological damage for the workers' health, in particular for workers' hearing ability, there is also a significant number of studies reporting that exposure to levels below the lower exposure action value (<80 dB(A)) can result in some psychological interference, particularly on the cognitive performance of the exposed individuals, in aspects like the short-term memory, attention and concentration (Smith, 1991; Belojevic et al., 2003; Arezes & Santos, 2008).

Therefore, it is assumed that all the education professionals and the students, although most of the time are not exposed to high sound pressure levels, thus with limited risk to their hearing ability, they are likely to be exposed to sound pressure levels high enough to interfere with their performance for a particular type of cognitive tasks, given the cognitive demands of their specific activity. Briefly, in some work environments the noise may be too low to have a significant impact on the workers' hearing, but may have an important effect in their cognitive performance (Arezes & Santos, 2008).

This paper aims at analysing if in some cognitive demanding occupations or jobs, such as teaching, the noise exposure levels they are exposed to may be high enough to impair their cognitive performance.

METHODOLOGY

The present study consisted in a cross-sectional and exploratory field study, which was conducted in a real context, a school of the 3rd cycle of the Portuguese education system. The study was held in the third period of the school year, between May and June, and was carried out during 4 weeks.

Considering the aims of this study, noise levels in the classrooms were measured throughout the 4 weeks considered in the study.

Sample Selection and Characterisation

The first premise for the subjects' selection and inclusion in the sample was their teaching activity, which should be framed within the requirements of this study. A large group of subjects was firstly selected and invited to participate in the study and to assist to a specific session regarding the study presentation and explanation of its purpose.

The final sample included all the subjects that voluntarily accepted the authors' invitation to take part in the study.

As each subject was involved in different teaching activities, subjects were divided in 2 different groups according to their type of teaching content/type. The subjects' division was made between those teachers with mainly theoretical classes and those with practical classes.

The first group of subjects was composed by 9 teachers that are mainly involved in room lectures with presentation of slides, in an expositive form. This group was designated as "T group". The second group of 7 teachers, consisted in teachers involved in practical sessions, lab classes, sports pavilion and dance hall, whose practical component is much stronger and requires greater verbal interaction and movement within the classroom. This last group was designated as "P group"

Overall, 11 sample subjects are female, 4 of which belong to the T component 7 and the group P. Male subjects were divided in 3 of the P group and 2 of the T group.

Subjects' age ranges between 27 and 41 years old, with an average of 33.6 (± 5.0) years old.

In terms of their professional characteristics, subjects have a mean seniority of 8.2 years of service, with a minimum and maximum of 1 and 15 years of service, respectively. Each teacher lectures an average of 26.9 hours per week, and the total weekly lecturing hours ranges from 23 to 29 hours.

Applied Tools

In the first phase of implementation, a self-assessment of the noise individual sensitivity to noise was applied to all the study sample subjects. This self-assessment was based on a previous developed and validated scale of noise sensitivity, the Weinsteisn's Noise Sensitivity scale (WNS) (Weinstein, 1978).

Although the noise exposure level for each worker was registered, according to some authors (Sailer and Hassenzahal, 2000) the $L_{A,eq}$ is not helpful in isolating prevailing reasons for experienced annoyance. It is known that some characteristics of the noise event, the considered task and the individual account for variation in the response to noise (Kjellberg et al. 1996). Moreover, and as identified in other studies, when evaluating the possible effects of noise exposure on cognitive performance, it is essential to include the subject noise sensitivity of each tested subject, as it may represent a source of important cognitive impairment.

Vastfjall (2002), citing also other authors, revealed that noise sensitivity is a major factor contributing to individual differences in noise perception, and Zimmer & Ellermeier (1999) clarified that the more sensitive people are to noise, the more annoyed they react.

Noise sensitivity is defined as the factor that induces individual variability in reactions caused by noise exposure. According to Kishikawa et al. (2006), noise sensitivity is not affected by the specific noise exposure.

Subjective noise sensitivity is usually measured by a self-reported questionnaire, both in the field and laboratory studies and one of the most frequent used scale is the applied scale, WNS, which is widely used since its creation (e.g., Dornic & Ekehammar, 1990; Luz, 2005; Miyakawa, 2008; Heinonen-Guzejev, 2009; Arezes et al., 2009).

WNS scale consists of 21 items, most of which express attitudes towards noise in general and emotional reactions to a variety of environmental sounds encountered in the everyday life. The psychometric properties (external validity, reliability, internal consistency, factor structure, and construct validity) of WNS have been reported previously (Ekehammar and Dornic, 1990; Zimmer & Ellermeier, 1999).

In this study a full version of the WNS was used, as described by Luz (2005). In this version, each question is presented with six-point options ranging from "agree strongly" to "disagree strongly" (coded from 1 to 6). Questions with reverse coding were later recoded according to the same score scheme as the other questions.

The sum of all items (after recoding) yielded the respondent's noise sensitivity, which may vary between 21 and 126 points. According to this scheme, a higher score denoted a higher sensitivity to noise.

For statistical analysis purposes, subjects were divided into 2 different groups, according to their noise sensitivity. These 2 groups were divided according to the obtained median for the variable WNS score. Accordingly, subjects were classified as being Noise Sensitive (S) or Non Noise Sensitive (NS), depending on their WNS score.

In accordance, approximately half of the subjects were classified as S subjects (N=11), and half as NS subjects (N=12).

In order to assess workers' cognitive performance it was applied a cognitive assessment test, which was carried out in a personal computer. This test consisted in a computerised battery of cognitive tasks, which measure verbal and spatial memory, working memory, attention, speed-of-processing, and visuo-spatial abilities (Cognitive Labs, 2008).

All the subjects were familiarised with the test before the data collection, as it was presented and explained to subjects in a previous session. During a period of 2 weeks before the study, subjects had the possibility to perform the cognitive test whenever they wanted.

Despite the short duration of the test (circa 2 to 3 minutes), from the carried out preliminary studies (Arezes and Santos, 2008) it was verified that it was no worth in carrying out more than 2 tests in the same day and for the same worker, which would most likely result in additional tiredness.

The cognitive test consisted in the presentation of an initial stimulus of a group of 3, or more, letters or shapes (such as the examples of Figure 1). After a few seconds the initial stimulus disappears and a smaller group (1 or 2) of letters or shapes is presented to the individual.

Subjects should answer the test by pressing, as quickly as possible, the right arrow key if it was the right choice (corresponding to an affirmative answer: YES), i.e., if one or more letters or shapes of the second group appeared in the first group, or by pressing the left arrow key if none of the letters or shapes appeared in the first group (corresponding to a negative answer: NO).

The result of the cognitive performance test was obtained through the parameter "*TSCORE*", which refers to the speed and accuracy of the answer (higher values correspond to better performances), and it considers both the average of the subjects' reaction time, in milliseconds, and the percentage of correct answers.

During all the study, subjects performed two tests per day, one in the beginning of the lecturing period and the other at the final of the day. Accordingly, 34 cognitive performance tests were carried out for each subject and the data of the total 544 cognitive tests were considered for the applied statistical analysis

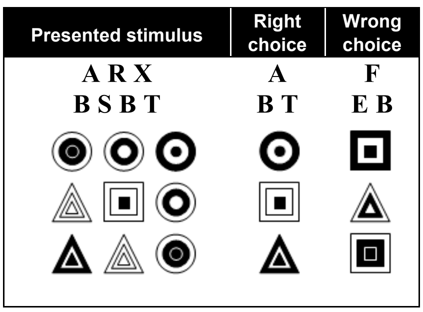

Figure 1. Examples of stimuli and expected responses to cognitive performance test

RESULTS AND DISCUSSION

Assessment of individual noise sensitivity

Table 1 presents the total values obtained from the application of WNS questionnaire. The obtained results show a general mean score of 68.3 points, median of 68 points and a standard deviation of 16.9 points. It is possible to notice that the measures of central tendency, mean and median, are very close.

As mentioned earlier, the subjects' sample was divided into two groups of different noise sensitivity, according to the median of the WNS score of the entire sample.

Therefore, individuals in both groups (P and T) were subjected to a classification according to their individual sensitivity to noise. Thus, all the subjects were classified as Sensitive to Noise (S) or Non-Sensitive to Noise (NS), depending of their scores on WNS.

For a score at or above the median (68 points), subjects were considered as being S and, likewise, a score below the median was classified as NS. Accordingly, and taking into account the median, approximately half of individuals within each group were classified as S and NS. As shown in table 1, 4 elements of the group P component were classified as S and 3 as NS. For the group T, 5 subjects were considered S and 4 considered NS.

Regarding the WNS score, it appears that the T group has a higher mean value (70.4 points) than the group P (65.6 points). To assess whether there is a relationship between two variables, a chi-square test was applied. Thus, differences between groups do not reveal to be statistically significant (X^2=0.559, p= 0.95).

Table 1. Subjects' classification according to WNS score

Parameter	P group	T group
Mean	65.6	70.4
sd	18.2	16.6
Min	39.0	49.0
Max	86.0	96.0

Sound Exposure Level

To determine the noise exposure level at which individuals have been exposed over the four weeks, the logarithmic mean of all the daily L_{eq} levels was applied.

Table 2 presents the (logarithmic) average values for the noise exposure for the different considered groups.

Table 2. Average values of noise exposure levels ($L_{A,eq}$) during the study

Parameter	P group	T group
N	9	7
Log. Mean (dB(A))	75,7	69,2
Min (dB(A))	72,3	63,8
Max (dB(A))	84,3	73,0

It is important to emphasise that there are important differences between the registered noise exposure levels between the subjects groups, as group P is exposed to an average level of 75.7 dB(A) and the group T has only an average level of 69.2 dB(A).

This difference of 6.5 dB(A) is quite relevant, as the used average levels assumed, in their calculation, that there is a 3 dB exchange rate, i.e., for each energy duplication an increase of 3 dB on the noise level will occur. Therefore, 6.5 dB of difference between the groups exposure is an important and significant difference, in terms of noise exposure.

It is also noteworthy that the maximum noise level reaches 84.3 dB(A) and the minimum 72.3 dB(A) for the P group, while the maximum value for the T group was 73.0 dB(A) and the minimum value was 63.8 dB(A).

Cognitive Performance Tests

The cognitive performance tests results can be expressed with different parameters. However, to simplify the analysis it was decided to use the parameter *TSCORE*, since it refers to the test overall score, including both the speed and precision of the answer. Accordingly, a highest *TSCORE* will correspond to better performances, and vice versa.

In order to analyse if the results presented in figure 2 (for the *TSCORE* parameter) varied over time (across the entire day and week), or if they depended on the teaching group (T or P) or individual sensitivity to noise (S or NS), an analysis of variance for repeated measures was applied.

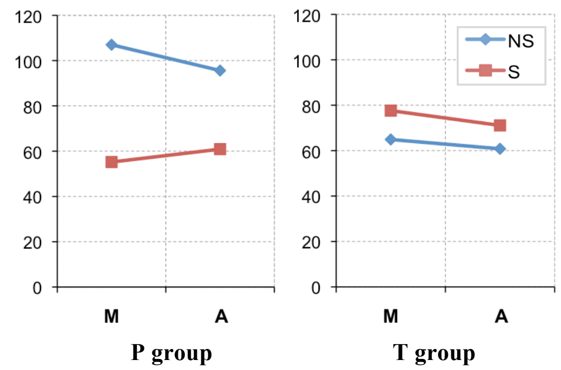

Figure 2 – Cognitive performance *TSCORE* (in points) for each subjects' groups.

Overall, it appears that there is a decrease in cognitive performance for both groups (P and T), when comparing performance of the morning and afternoon. An exception occurs in the group of P and for noise sensitive subjects (red line in the left chart of Figure 2), in which there is a slight performance improvement from morning to afternoon (from 55.2 to 60.9 points, respectively for morning (M) and afternoon (A) periods.

When analysing the possible effects of noise exposure on subjects' cognitive performance considering the division between P and T groups, and between noise sensitivity and non-sensitive, a statistical analysis of the obtained values was carried out. In this analysis, it was found that the interaction effect between the period and component teaching group is statistically significant ($F=5.326$; $p=0.040$).

These differences seem to reveal that it is possible that noise interferes with cognitive performance of subjects over the different weeks. Indeed, it appears that the subjects in group P showed better cognitive performance results than the T group, both for morning and afternoon (comparing lines from the left and right chart of Figure 2).

The obtained results also highlight the performance of those non-sensitive subjects (NS) in the group P, which presented the high values for *TSCORE*, both in the morning and afternoon.

Despite the highest noise exposure of subjects in group P, 75.7 dB(A), it is also in this group where it is possible to find the best performance results.

Generically, it seems clear that the group P presents a better overall cognitive performance, for both periods, and that there is a decrease in almost all conditions between morning and afternoon performances.

From the obtained results it also seems important to highlight that the highest difference in performance between groups is observed in the more noise exposed group and between the non-sensitive and sensitive noise subjects.

Accordingly, it seems that noise may play a role in the cognitive performance impairment, but this seems to be more relevant for noise sensitive subjects.

CONCLUSIONS

This study aimed at analysing the possible impact of teachers' noise exposure in the classrooms on their cognitive performance.

Despite the average daily noise exposure levels in the classrooms were typically below the lower exposure action value defined in the legislation (80 dB(A)), it was possible to registered maximum noise exposure levels, during the study period of 4 weeks, of 84.3 dB(A) for the group of teachers involved in more active classes, defined in the study as 'P group' .

From the obtained results it is possible to draw some important insights, such as:

- Individuals from both groups of teaching activities (T and P) showed lower performance results after being exposed to classroom noise;
- Amongst teachers with higher noise exposure, the best performance was obtained for those who have scored lower in the noise sensitivity scale. It is likely that due to their low sensitivity to noise they may be less susceptible of cognitive impairment.
- It seems that there is a clear trend in the cognitive impairment due to noise exposure. However, the obtained results are not consistent across all the analysed variables.

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