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Noise Exposure Level While Operating Electronic Arcade Games as A Leisure Time Activity

Seyed Mohammad MIRBOD*, Ryoichi INABA, Hideyo YOSHIDA,
Chisato NAGATA, Yoko KOMURA and Hirotoishi IWATA

*Department of Hygiene, Gifu University School of Medicine,
40 Tsukasa Machi, Gifu 500, Japan*

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Abstract: In order to study noise levels associated with electronic arcade games, noise measurements were made in 3 selected game centers and 192 samples were taken in each location. The background noise was recorded at a level of 61 dB(A) and 64 dB(C). When the electronic games were performed these levels of noise reached to 88~90 dB(A). The 1/3 octave bands analyzing sound pressure levels showed that more intense noise levels arose in a frequency range between 0.5 and 2.0 kHz. The computed values for noise pollution levels (L_{NP}) and L_{90} (fast response A-weighted sound level exceeded 90% of the measurement time) ranged from 93.3 to 96.6 and from 85.1 to 87.3 dB(A), respectively. Concerning our results and according to Melnic (1979), it was estimated that these levels of noise might cause 4–8 dB temporary threshold shift (TTS) at 4.0 kHz in an individual with less than one hour of exposure to such a level of noise.

As for the employees of the 3 game centers, the 8-hr equivalent continuous sound levels ($L_{eq,8}$) were in the range of 80.3~87.5 dB(A), although their exposure time could not be exactly determined. It was suggested that:

- 1) The maximum levels should be limited to a reasonable level, either by the manufacturers or by the game center owners;
- 2) Education programs in industry should inform the employees about other factors outside the work that may affect their hearing; and
- 3) For policy-making on hearing conservation, recreational warning and standards should be established.

Key words: Leisure time—Noise level—Electronic games—1/3 Octave band center frequency— $L_{A,eq}$ — $L_{C,eq}$ —Noise pollution

* To whom correspondence should be addressed.

INTRODUCTION

Noise, commonly, identified as unwanted sound, has long been well known for its relation to possible adverse effects on auditory and non-auditory mechanisms (see for example Smith *et al.*¹⁾, Kent *et al.*²⁾). Occupational noise is not, of course, the only cause of hearing loss in a noise-exposed population. There are three types of hearing loss that occur commonly in addition to occupational hearing loss. One is called presbycusis³⁾, the loss that occurs naturally from aging. Another is sociocusis, an expression first coined by Glorig (Cohen *et al.*⁴⁾), which is usually taken to mean the loss caused by non-occupational sources such as noisy leisure time activities. The third category of hearing loss is a very broad one, and includes all kind of medical abnormalities.

The concern of noise levels in society has prompted researchers to study recreational activities and to report on their possible harmful effects on hearing sensitivity. Johnson *et al.*⁵⁾ investigated the noise exposure levels during a 31-day period for an individual not exposed to industrial noise. Their results showed that 69% of noise exposure events were due to leisure time activities which could increase the 31-day average sound level from 71 to 76 dB. Barone *et al.*⁶⁾ conducted a survey on the hearing abilities of workers with industrial jobs (n = 830). They could demonstrate that noisy hobbies were significantly associated with workers' hearing losses. According to the results of a study by Franks *et al.*⁷⁾ factors outside the work environment such as hobby history could be contributing to the changes noted in hearing.

Leisure time activities such as listening to or playing amplified music^{8,9)}, using stereo earphones^{10,11)}, riding snowmobiles^{12,13)}, using motorized model airplanes¹⁴⁾, target practice with air guns¹⁵⁾, and entering discotheques^{16,17)} have been shown to be in part responsible for hearing loss. Hence, it is a matter of concern to be aware those factors not under the control of the company may affect the hearing of the employees.

There has of late been much popular interest in the subject of electronic games as a leisure time activity in Japan, and one might assume that the blue/white collar population has chances to spend some of their leisure time operating electronic games. However, in the literature review there was no report on this topic. Therefore, the study described below was initiated with the following aims:

- ① To quantify noise levels of electronic games under actual operating conditions;
- ② To estimate whether the measured noise levels in game centers could induce temporary threshold shift (TTS) in an individual within a certain exposure time (1-2 hrs) and;
- ③ To make recommendations for control if a high level of noise exists.

EQUIPMENT AND PROCEDURES

Preliminary visits to 6 selected game centers showed little differences between managing style, activities, and noise sources. Therefore 3 game centers were selected for this study.

A sound survey of the noise levels at each of the 3 game centers was conducted utilizing the Rion Sound Level Meter (SLM)—type NA-24, and the Rion 1/3 Octave Band Real-Time Analyzer—type SA-27 which is a miniature programmable microprocessor/data logger for sampling, storing, and processing sound level information. The calibration before and after each measurement was made according to the manufacturer's recommendations. The noise level sampling constant period was adjusted to 0.1 sec (*fast response*) and the level average over 5 sec (50 data) was considered as one sample. The value of one sample could be computed as follow:

$$\text{Level average } (L_{\text{AVE}}) = 10 \log \left\{ \sum_{i=1}^N (10^{L_i/10}) / N \right\} \text{ dB}$$

where,

L_i = Instantaneous data level, and;

N = Number of data

The time history over 159 noise samples [L_{AVE} , dB(A) *fast response*] was drawn and the data were printed out at the end of each sampling period.

In each game center background noise levels (noise from all sources other than the particular sound that is of interest, i.e., the sound not being considered for noise monitoring)¹⁸⁾ were measured while electronic games were on, but not being operated and music (mellow sounds) could be heard through the loud speakers. It should be mentioned that there were 2–3 people (included the first author) in the game centers during the background noise monitorings.

Because people are normally seated while operating electronic games, the sound level meter was mounted on a tripod and its height above the floor was adjusted to about 1.1 m.¹⁹⁾ In each game center 192 samples during a 16-min period (electronic games in operation) were taken and the following acoustic parameters were then recorded: "A- and C-weighted" equivalent continuous sound level ($L_{A,eq}$), ($L_{C,eq}$) and levels which exceeded for 5, 10, 50, 90 and 95% of the sampling period (L_5 , L_{10} , L_{50} , L_{90} , L_{95}) [dB(A), *fast response*].

Moreover, by using the following equation the noise pollution level (L_{NP}) which is a procedure for estimating annoyance caused by any noise source was determined²⁰⁾.

$$\text{Noise Pollution } (L_{NP}) = L_{50} + d + d^2/60 \text{ dB(A)}$$

where,

$$d = (L_{10} - L_{90}) \text{ dB(A)}$$

The equivalent continuous sound levels [L_{eq} , dB(A)] for employees in the game centers were evaluated using Sound Level Meter NL-02 (Rion Co.) and the measurement period was set to 1 or 8 hr ($L_{eq, 1}$, $L_{eq, 8}$).

Statistical procedures

By using the statistical analyses system (SAS) graph²¹⁾ the 1/3 octave bands noise levels were plotted for L_5 , L_{10} , L_{50} , L_{90} and L_{95} dB(A). To test the significance level within particular results, Student's *t*-test was used. Statements of statistical significance were based on a probability level of 5%.

RESULTS

The number of electronic games located in the three selected game centers (I, II, III) together with their background noise levels are shown in Table 1. The average background noise levels (mean $\pm$ SD) were obtained by placing the sound level meter in 14 different locations in both game center No. (I) and (II); and in 12 places in game center No. (III). The results obtained showed no significant differences in the background noise levels inside the game centers, and noise was recorded at levels of about 61 dB(A) and 64 dB(C). Due to the similarity in the background noise levels inside the game centers, it was assumed that external factors such as traffic noise might not affect interior noise levels. To compare the noise levels during the week-days and week-ends, game center No. (III) was considered for further noise measurements and a noise sampling during week-ends (two times) was performed. However, no significant differences ($p > 0.05$) could be demonstrated in the noise levels during the week-days [61.6 $\pm$ 1.2 dB(A)] and week-ends [62.1 $\pm$ 1.5 dB(A)].

Placing the SLM (NA-04) in a variety of positions in the arcades (during game operation) resulted in little or no variation in the readings, therefore a diffuse sound field was approximated.

In Fig. 1_(I-III) the time history of L_{AVE} [dB(A), *fast response*] over 159 samples in each game center are shown. As can be seen in Fig. 1_(I), the background noise

Table 1. The mean values ($\pm$ SD) of background noise levels and numbers of electronic games in 3 selected game centers.

Game center	No. of electronic games	No. of noise samplings	Background noise §	
			dB (A)	dB (C)
I	18	14	61.2 $\pm$ 1.8	64.3 $\pm$ 1.1
II	23	14	62.0 $\pm$ 1.2	64.8 $\pm$ 1.9
III	28	12	61.6 $\pm$ 2.3	64.0 $\pm$ 1.7

dB = 20 log P/P₀, P₀ = 20 μ Pascals

§, No significant differences in background noise levels could be demonstrated.

Fig. 1(I-III) The time history over 159 samples in the 3 game centers. The sound pressure levels are given as level average [L_{AVE} dB (A), *fast response*, re. 20 μ Pascals]. The L_{AVE} over 5 sec was considered as one sample.

Table 2. Equivalent continuous noise level (L_{eq}) by center frequency octave bands in the three selected game centers when all electronic games were operated. The ranges, mean values and S.D. were obtained from 192 samples in each game center (16 min sampling period).

Sampling location	Overall noise level		Center frequency octave bands (Hz)							
	dB (A)	dB (C)	125	250	500	1000	2000	4000	8000	
I	Range	89.7~92.1	90.1~93.2	59.1~62.5	73.9~78.7	83.0~86.4	83.1~88.9	81.2~85.3	75.0~78.1	60.1~63.2
	Mean±SD	90.2±2.4	92.0±1.3	61.4±2.1	77.8±3.8	85.4±3.2	87.2±4.8	83.4±3.5	77.4±2.1	62.8±2.7
II	Range	90.1~92.9	90.8~93.6	77.1~80.5	79.0~83.1	84.2~88.7	82.0~88.5	80.1~83.5	75.0~78.6	59.0~63.1
	Mean±SD	91.5±2.1	92.4±1.1	79.7±2.8	80.7±2.1	87.5±3.1	87.8±4.1	82.0±2.5	77.5±1.7	61.0±2.0
III	Range	90.1~93.5	91.1~94.9	74.5~78.9	83.9~89.1	84.5~89.0	80.7~89.0	78.5~85.7	70.0~74.2	58.1~62.7
	Mean±SD	92.0±2.7	93.1±1.8	76.3±2.8	88.3±3.5	88.1±2.7	84.6±3.6	81.1±3.0	72.3±2.5	59.1±1.7

Fig. 2. Sound pressure levels [dB (A), *fast response*, re. 20 μPascals] exceeded for 5, 10, 50, 90 and 95% of the sampling period by 1/3 octave band center frequencies (kHz) in game center No. (III).

Table 3. The over-all noise levels [dB (A), dB (C)] and some of the acoustic parameters [dB (A)] in 3 selected game centers when all electronic games were operated.

Sampling location	Overall noise (Leq) [†]		L _N [*] , [dB (A)]			L _{NP} [☆] dB (A)
	dB (A)	dB (C)	L ₁₀	L ₅₀	L ₉₀	
I	90.2	92.0	90.5	87.4	85.1	93.3
II	91.5	92.4	92.0	89.7	86.5	95.7
III	92.0	93.1	92.4	91.1	87.3	96.6

[†]Leq=Equivalent continuous noise level;

^{*}L_N=Levels exceeded for 10, 50 and 90% of the sampling period in dB (A), *fast response*;

[☆]L_{NP}=Noise pollution level in dB (A).

[L_{NP}=L₅₀+d+d²/60 dB (A), d=(L₁₀-L₉₀) dB (A)]

level from 61 dB(A) reached to 88–90 dB(A) noise level (overall) when the electronic games were being operated. It should be cited that the values are representative not only of the games, but also of included noise from the players, observers, and background music. According to the results obtained, the differences between the noise levels during actual operating conditions and background noise were more than 10 dB(A), therefore no correction was considered in the results obtained.

In Table 2 the center frequency octave bands noise levels (Mean±SD and Ranges) are listed. As can be seen, the C-weighted noise levels were typically 2–3 dB higher than the measured dB(A) levels. Therefore, it could be reasoned that most of the measured sound levels were not at high frequencies²². Assessment of the results listed in Table 2 showed that in game center No. (I) the highest noise levels (87.2±4.1 dB) were recorded at 1.0 kHz frequency octave band. As for game center No. (II), two frequency octave bands, 0.5 and 1.0 kHz had the highest noise levels (87.5±3.1 and 87.8±4.1 dB, respectively). In game center No. (III) noise at the frequency octave bands 0.25 and 0.5 kHz were 88.3±3.5 and 88.1±2.7 dB, respectively, which were higher than the other center frequency octave bands noise levels.

The recorded values (Table 2) showed that noise in game center No. (III) had a slightly higher intensity than the two others. This higher noise level could be explained by a larger number of electronic machines located in game center No. (III) (Table 1). However, the frequency component was almost the same in 3 places and a high level of noise was recorded with concentration at frequency ranges from 0.5 to 2.0 kHz. In Fig. 2 the 1/3 octave band sound pressure levels for L₅, L₁₀, L₅₀, L₉₀ and L₉₅ dB(A) are shown. The plotted values for L₁₀, L₅₀ and L₉₀ had a mean noise intensity exceeding 82 dB(A), particularly at 0.8 and 1.0 kHz. In Table 3 the L₁₀, L₅₀, L₉₀, together with L_{NP} [dB(A)] are shown. The L₁₀, L₅₀ and L₉₀ values in the game centers ranged from 90.5~92.4, 87.4~91.1 and 85.1~87.3 dB(A), respectively. The computed value of L_{NP} in these 3 electronic arcade game centers ranged from 93.3 to 96.6 dB(A).

The $L_{eq,1}$ values in the 3 game centers were in the 86.5~89.8 dB(A) range, while the $L_{eq,8}$ values were in the range of 80.3~87.5 dB(A) which was slightly higher than the recommended occupational noise exposure level for a period of 8 hr [85 dB(A)]²³⁾. It should be mentioned that these values were obtained by performing two noise samplings in each game center. The values of $L_{eq,8}$ might be considered as the daily noise exposure levels of employees, though their daily noise exposure time could not be exactly determined. An additional noise monitoring during week-ends (two times) showed that $L_{eq,8}$ had almost the same range as the measured values during week-days, however, the $L_{eq,1}$ values during week-ends had a slightly higher intensity (87.5~91.3 dB(A)) than those recorded during week-days. This could be explained by a larger number of people operating electronic games during the weekends.

It should be mentioned that in this study an attempt was also made to interview the employees of the game centers and to conduct audiometric assessments for them, but the response was poor. Therefore, the probable noise-induced permanent threshold shifts (NIPTS) among them were estimated utilizing the graph introduced by Passchier-Vermeer²⁴⁾ in which the median estimated NIPTS produced by 10 years or more of exposure to noise at the indicated A-weighted level (8 hrs/day, 250 days/year) could be easily read at various frequencies. Using the conditions mentioned above, the NIPTS of game centers' employees were appraised as 13, 17 and 11 dB at 3, 4, and 6 kHz, respectively.

DISCUSSION

Noise is a ubiquitous environmental stressor, and it is appropriate to investigate a person's daily noise exposure events. In recent years there have been numerous studies of occupational noise exposure and possible outcomes such as hearing loss and elevated blood pressure. Non-occupational sources of noise have also been taken into account by some researchers. Institute of Hearing Research²⁵⁾ in 1986, by a review of papers on noisy hobbies, suggested that the risk of hearing threshold shift from non-occupational noise is not great but that it cannot be wholly discounted, especially if we take into account the total of occupational and non-occupational noise exposure effects. They concluded that if occupational hearing conservation criteria were set at 85 dB(A), leisure noise would make a small but definite contribution to their overall noise exposure. Axelsson *et al.*²⁶⁾ also conducted a survey on noisy leisure time activities among 538 teen-age boys and they demonstrated that those individuals who reported using noisy hobby machines had hearing difficulties in the left ear at 1 kHz. Townsend *et al.*²⁷⁾ in a survey of hearing sensitivity of a rural mid-Michigan population (n=1,325 adults over 15 years of age) concluded that people who had never had any industrial noise exposure had thresholds almost as poor as those who had worked in factories.

Concerning this background, more attention needs to be paid to the often neglected factor of leisure noise exposure and its parameters, i.e., the numbers exposed, the patterns, and durations of their exposure in the general population. However, it should be mentioned that some difficulties might be encountered with data collection on leisure time activities. For instance, for many people it might be difficult to remember their weekly exposure hours, or how many times a year an individual engaged in leisure activities and for how many hours at a time.

In the present study we tried to verify the noise levels of electronic games which are amongst popular hobbies in Japan. The results obtained showed that the noise levels (L_{AVE}) of electronic games during actual operating conditions were recorded at a level of 88~90 dB(A). These results were in good agreement with those reported by Plakke²⁸⁾. The spectral readings obtained (Table 2 and Fig. 2) indicated that noise levels during actual operation of electronic games were at least 10 dB higher than the background noise, hence, in the results obtained no correction was applied²⁹⁾. The highest sound pressure levels at about 82 dB arose in the frequency ranges between 0.5 and 2.0 kHz. These overall noise levels might be related to the conditions of each arcade including the care and maintenance of the machines, the types of machines, and the location, as well as the specific room dimensions of the arcades. However, it should be mentioned that the interior noise intensity of the 3 selected game centers were almost at the same level (Tables 2 and 3). Considering the values of L_{90} (Table 3) and according to the graphs introduced by Melnic³⁰⁾, these levels of noise [range from 85.1 to 87.3 dB(A)] might cause about 8 dB temporary threshold shift (TTS) at 4.0 kHz in an individual with less than 1 hr exposure. And if the exposure duration increases to 1–2 hrs, then the TTS value would possibly increase to a level of 10 dB (at 4.0 kHz) which would require 2 to 4 hrs for recovery after exposure. The adverse effect of noise at these levels on hearing appears minimal if game operators stay in an arcade for shorter periods of time and are in a more quiet environment off the games.

In addition to the risk of hearing damage, the concomitant stresses faced by performing these kinds of games should also be noted. It has been reported that such a high noise intensity may interfere with subsequent sleep processes³¹⁾, contribute to increased cigarette smoking behavior³²⁾, or the performer of these games may experience a strong feeling of anxiety³³⁾.

This non-work-related noise exposure in a younger population that has had less lifetime of industrial noise exposure may be a relatively important determinant of hearing loss. Kryter³⁴⁾ suggested that industrial workers, especially those younger than 30 years of age, are exposed to more non-industrial and leisure time noise than the general population. He has shown that this excess noise exposure is sufficient to account for significant additional hearing impairment in workers routinely exposed to average sound levels between 80 and 90 dB(A).

One important consideration is that the sound is an integral part of the

fascination of electronic games, and therefore a particular factor of their appeal. However, the maximum noise level produced by electronic games should be limited to a reasonable level, either by the manufacturers or by the game center owners. This might help in reducing such non-occupational noise exposure; a matter that is otherwise extremely difficult to control and regulate.

We suggest that company education programs should stress the importance of good hearing conservation practices on and off the job, and inform the employees about other factors outside the workplace that may affect their hearing.

Further researches to determine the noise levels in other game centers, duration and the exposure periods of a large random sample whole-population are needed. With the benefit of such studies there would be confidence that proper decisions could be made for the health and safety of all concerned.

In future surveys more attentions need to be paid to the occupational noise received by employees in the leisure industries.

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