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Reactions to night noise due to leisure activities

S. Feijoo
Departamento de Física Aplicada, Facultad de Física, 15782 Santiago de Compostela, Spain

ABSTRACT

One particular form of neighborhood noise is due to leisure activities that take place during nighttime hours. Most cities in Spain are actually affected, and numerous neighbors' complaints are made before the town councils. In this paper a study of the night noise levels in places packed with leisure activities is presented. Continuous measurements were carried out in each of 13 selected homes from 23.00 p.m. to 7 a.m. Two measurements were done during busy nights and one measurement was done during a quiet night. The noise indices $L_{Aeq,15}$, L_{Amax} , L_{night} and the yearly average of night time noise level, $L_{night,outside}$ in each point were obtained. A social survey was carried out asking only the residents of the specific home where sound levels were measured that night. They had to answer several questions about their sleeping quality. Although results indicate that there is a good correlation between Lnight and annoyance ratings, a closer inspection of data indicated that annoyance ratings followed a bimodal distribution: the presence or absence of the unwanted sound source conditions the appearance of annoyance and of sleeping problems, to some extent independently of sound levels.

1. INTRODUCTION

In some southern European countries, like Spain, the problems caused by noise due to night life activities are commonplace, particularly those originated by people drinking in the outside and by the music emitted by pubs, discos or musical bars. Most cities in Spain are actually affected by noise in the areas where these activities take place and numerous neighbors' complaints are made before the town councils (see, for instance the web page dedicated to noise in Spain http://www.ruidos.org/[1]).

The approach of the European commission regarding night noise has been to consider its long-term health effects since they are better correlated with acoustic indicators obtained over a long period, such as the yearly average of night time noise level, $L_{night,outside}$. Other indicators currently used for regulatory purposes, such as the A-weighted equivalent noise levels, L_{Aeq} , or the maximum level per event, L_{Amax} , are useful to predict short-term effects[2]. Intermittent noise causes larger reactions than continuous noise. Intermittent noise is characterized by a distance of more than 10 dBA between the equivalent sound pressure level and the maximum levels[3] .

Major sleep disturbances caused by noise include lengthening the time to fall asleep, awakenings in the middle of the night, or too early wake-up time. Insomnia is characterized by difficulty falling asleep, maintaining sleep, waking up too early or non-refreshing sleep. Approximately 10% of the population have chronic insomnia, and between 30-50 % of the population suffers occasionally from insomnia[4].

Santiago de Compostela is a town of approximately 100.000 people, with many university students and tourists enjoying its nightlife all year round. The town is divided in two areas: the new city and the old city. The streets of the old city are short and narrow and traffic is controlled: only residents are allowed to enter the area. As a result, traffic in the old zone is sparse. Complaint reports on night noise forced the town council to start a study about the situation in 10 streets, 4 of them in the new city and the other 6 streets in the old city. According to the Municipal Register, 300 people live in the 6 streets of the old city, and 2.200 people live in the 4 streets of the new city. The noise ordinance of Santiago de Compostela fixes a limit of 55 dBA for the continuous equivalent level measured during the night. Residents of those streets complained about the noise produced by people in the outside and about the music emitted from the inside of nightclubs and bars. An added problem is that most places remain opened well beyond authorized closing times.

In this study some homes were selected to carry out noise measurements during the night and the people were asked several questions about their sleep quality, and about their perception of the noise produced in those particular nights. In this way it is possible to establish a direct relationship between the noise levels in the outside and the response of the affected people.

2. METHOD

A. Selection of measurement points

13 homes were selected, one per street, except in 3 the streets, for which two points were selected. Most of the selected homes occupy the first floor of their buildings, except those in Republica Argentina street (2º floor), Via Sacra (3º floor), and San Paio (4º floor).

B. Equipment

Two sound level meters were used: Rion NL-14 and Brüel & Kjaer modular Precision Analyzer 2260. Besides, two acoustic calibrators were used: Rion NC-73 and Brüel & Kjaer 4231. Both the sound level meters and the acoustic calibrators passed an external calibration procedure done by a certified laboratory.

C. Measurements

Continuous measurements were carried out in each of the 13 selected homes from 23.00 p.m. to 7 a.m. Two measurements were done during busy nights (Thursday, Friday and Saturday) and one measurement was done during a quiet night (Monday).

D. Noise indices

The continuous equivalent sound level during 15 minutes, $L_{Aeq,15}$ and the corresponding maximum value during that period, L_{Amax} ,were measured in each point. Then the continuous equivalent sound level during 8 hours, L_{night} was computed for each point.

$$L_{night} = 10\log\left[\frac{1}{N}\sum_{i=1}^{N}10^{0.1\left(L_{Aeq,15}\right)_i}\right] \quad (1)$$

where $(L_{Aeq,15})_i$ represents the continuous equivalent level during one of the 15 minutes period, and N is the number of 15 minutes periods along the 8 hours (currently 32 periods).

With the L_{night} obtained from the two busy nights and from the quiet night it is possible to compute an approximation to the yearly average of night time noise level, $L_{night,outside}$ in each point. Considering that a year has 364 nights (52 weeks) and that there are 4 busy nights per week (Wednesday, Thursday, Friday and Saturday), and 3 quiet nights, one year has a total of 208 busy nights and 156 quiet nights. This is a conservative approach, since at least in two of the three quiet nights most bars and nightclubs are working.

$$L_{night,outside} = 10\log\left[\frac{1}{364}\left(104\cdot 10^{0.1L_{night,1}} + 104\cdot 10^{0.1L_{night,2}} + 156\cdot 10^{0.1L_{night,3}}\right)\right] \quad (2)$$

where $L_{night,1}$ represents the continuous equivalent level obtained during the first busy night; $L_{night,2}$ represents the continuous equivalent level obtained during the second busy night; and $L_{night,3}$ represents the continuous equivalent level obtained during the quiet night.

E. Social survey

The social survey was carried out asking the residents of the specific home where sound levels were measured that night. Residents were personally interviewed the following morning and they had to rate the degree of annoyance produced by night life activities in an 11 point scale: from 0 (no annoyance) to 10 (extremely annoying). Other questions were: a) Do you have difficulties falling asleep due to noise during busy nights? Approximately, how long does it take you to fall asleep?; b) Do you wake up in the middle of the night due to noise during busy nights? How many times? Approximately, how long does it take you to fall asleep again?

3. RESULTS

A summary of the mean $L_{Aeq,15}$ and L_{Amax} values can be seen in Table 1. 13 homes were selected for the measurements. After measuring $L_{Aeq,15}$ and L_{Amax} during the whole night, L_{night} was computed. One-way ANOVAs performed on the $L_{Aeq,15}$ data of each point showed significant differences in $L_{Aeq,15}$ between the busy nights and the quiet night in all points ($p<0.01$), except for the Sacra Street, located in the old city. One-way ANOVAs performed on the L_{Amax} data of each point showed no significant differences between the mean maximum values of the old and of the new city in any point, either for busy or quiet nights. Significant differences in L_{Amax} between the busy nights and the quiet night showed up in all points ($p<0.01$), except for the point located in Republica Argentina, 48 (new city). Mean differences in L_{Amax} between the busy and the quiet nights ranged between +1.1 dBA (for the Sacra Street) and +16.6 dBA (Entremuros Street). Fig. 1 shows the L_{night} values obtained in the two busy nights and in the quiet night. Mean differences in L_{night} between the busy and the quiet nights ranged between -0.5 dBA (for the Sacra Street) and +17.4 dBA (Entremuros Street). Again, there seems to be some difference between the sound levels of both zones during quiet nights. One-way ANOVAs performed on the L_{night} data showed that the sound levels of the old and new city are not significantly different during either quiet or busy nights. Fig. 2 shows the values of $L_{night,outside}$ computed using equation (2).

The social survey was answered by 13 residents (one per home) three times, one time per measurement night. Two of the residents were under medical treatment due to problems related to night noise (depression, nervous disorders). Table 2 shows the results. Average annoyance rate during the busy nights was 7.8, much higher than the annoyance rate during quiet nights, 1.4. Around 40% of the residents experienced difficulties in falling asleep during busy nights in contrast with the absence of difficulties in the quiet nights. A similar trend was observed for the awakenings during the night: around 56% of the residents were awakened by noise during busy nights, while only one person in the new city declared to be awakened by noise during a quiet night. The residents that manifested difficulties in falling asleep estimated that they needed around 1 hour to sleep again, approximately the same time needed by the people awakened by noise at night to fall asleep again. One of the residents took sleeping pills during noisy nights. Another resident admitted that one exterior dormitory had to be rendered useless due to night noise.

Figure 3 shows the relationship between the L_{night} values obtained in the three nights and their corresponding annoyance rates. To avoid the variability introduced by individual responses to questionnaires of annoyance, the annoyance data were regrouped by averaging responses corresponding to sound levels intervals of L±1 dBA[5,6] . The linear correlation coefficient obtained was R= 0.94, significant at the 0.01 level, which explains 88% of the variance in the data. The correlation between the L_{Amax} values obtained in the three nights and their corresponding annoyance rates can be seen in fig. 4. The linear correlation coefficient was R= 0.86, significant at the 0.01 level, which explains 74% of the variance in the data.

Despite the seemingly good relationship between annoyance ratings and sound levels, there is some evidence that the actual relationship might be conditioned by the existence of a clear-cut division between the reactions of the people to noise in busy or quiet nights. The distribution of annoyance ratings can be seen in fig. 5, with the gray color representing the values of quiet nights and the white color representing busy nights. It is clear that annoyance ratings are distributed as a bimodal function. No difficulties for sleeping are reported in absence of the noise produced by night life activities. Only one person in the new city declared to be awakened by noise during a quiet night.

Some objective characteristics of noise may have particularly strong effects on people, like intermittent noise, low-pitch components, tonal noise or impulse noise[3,7]. Inspection of data showed that in all measurement points, of both busy and quiet nights, the difference between the equivalent sound pressure level and the maximum levels were higher than 10 dB, indicating the presence of intermittent noise. Inspection of noise spectra showed two distinct models, depending on the predominant source. Fig. 6 and 7 show both types: the spectrum of fig. 6 corresponds to a point where the predominant source is the human voice, while that of fig. 7 corresponds to a point where, apart from the human voice spectrum, the low frequency components associated with loud music and with traffic are clearly seen. Nevertheless, annoyance ratings did not show a specific trend depending on the presence or absence of low-frequency tonal components: for both examples, the annoyance ratings were fairly similar.

4. DISCUSSION

The sound levels measured in the streets packed with night life activities of Santiago de Compostela are comparable to those measured in other Spanish cities[8-14]. The estimated values of $L_{night,outside}$ are higher than the levels recommended by the World Health Organization (WHO)[2]: no substantial biological effects for $L_{night,outside} \leq 30$ dBA, and danger for public health for $L_{night,outside} > 55$ dBA. Depending on the insulation, the maximum values inside the homes are also higher than the recommendations of the WHO. If a conservative insulation value of 30 dBA is considered, the values of L_{Amax} measured in the outside result in maximum levels inside higher than 40 dBA during busy nights and higher than 35 dBA during quiet nights in most points. These levels should produce the appearance of biological and medical effects affecting the sleep quality and well-being of the residents.

The general social survey shows that the sleep quality of 80% of the residents is affected by night noise. Similar studies carried out in Valencia show a much lower number of people affected: 30% were awakened by noise at night in [8], and between 55-60% in [11]. An interesting finding of the study of Guijarro [11] is that the percentage of people who experienced difficulties in falling asleep was higher for places with night life activities, 58%, than in places with traffic noise, 33%. A similar trend was observed for awakenings: 42% in places with night life activities vs. 22% in places with traffic noise. However, sound levels were higher during the night in places with traffic noise than in places with night life activities. This result was replicated in the particular social survey of the present study, where sleep problems are experienced by higher percentages of people in the old city, where traffic is regulated and scarce. This is in itself a contradiction, since the presence of an additional annoying source should contribute to a higher number of sleep problems in the new city. Only 11% of the residents of the new city considered traffic as the most annoying source. The annoyance ratings obtained in the particular survey of the old city are also higher than those of the new city (8.1 vs. 7.1).

The results show that it is difficult to establish a dose-effect relationship due to the complexity of the interaction of all the factors involved[15]. The almost complete absence of effects during quiet nights and the bimodal distribution of annoyance ratings indicate that the presence of the unwanted noise source conditions the appearance of effects. It is known that transportation noise usually leads to sleep disturbances[16] and that it is more detrimental to sleep quality than sounds produced by natural sources, such as frog's croaking[17]. An interesting finding of the study of Guijarro[11] is that the percentage of people who experienced difficulties in falling asleep was higher for places with night life activities, 58%, than in places with traffic noise, 33%. A similar trend was observed for awakenings: 42% in places with night life activities vs. 22% in places with traffic noise. However, sound levels were higher during the night in places with traffic noise than in places with night life activities. In the study of Kuwano[18], songs and people's talk were found disturbing even if their sound levels were low, in contrast with other sounds which did not have a particular meaning. A psychological explanation could be based on Grimwood[19], who found that noise apparently due to thoughtlessness or lack of consideration usually elicits an adverse response. After interviewing the residents at home, it is clear that they perceived the sound produced during busy nights as an aggression. Residents of both the new and the old city considered people in the streets and the music emitted by nightclubs as the most annoying sources during busy nights[20]. Objective characteristics of the noise, such as its spectral content, were not useful to find an explanation of the people's reactions before the different types of noise.

Apart from the complexity of the problem, it was difficult to record precise answers of the residents about their sleeping quality in the particular social survey. The answers to several of the items, such as the time needed to fall asleep or the number of times the subject was awoken by noise, were often vague and could not be used to establish the effects of the noise. Another factor is the difference in the perception of noise depending on the situation of the bedroom at home, something already noted by Guijarro[11]. Annoyance ratings are directly related to noise levels and seem to be more representative of the noise situation, but it is difficult to use them to predict the effects of noise: in the present study annoyance ratings under 5 seem to guarantee an almost complete absence of effects, but those ratings were associated with the absence of noise due to night life activities. An annoyance rating of 5 would correspond in Figure 4 to an L_{night} level higher than 60 dBA, clearly an inappropriate option.

One last question is the election of an adequate noise index and its corresponding threshold level. A long-term index such as $L_{night,outside}$ tends to blur the differences in noise levels between the busy nights and the quiet nights, and does not make any distinction between them: it does not take into account the different reactions of people exposed to both situations. Even in quiet nights, at least in 10 of the 13 homes sound levels greater than 55 dBA were measured while not eliciting almost any adverse response (in a conservative approach that means that $L_{night,outside}$ should be also greater than 55 dBA). A short-term index such as L_{night} seems more adequate but it would be advisable to make a distinction about the nature of the sound source. Even shorter-term measures lead to similar conclusions and can be restricted to the periods during which the night life activities remain opened, thus linking the sound levels to the nature of the source. The second part of the question concerns the threshold level which should be considered. It is sure that the lowest level proposed by the WHO (30 dBA) would guarantee good conditions for sleep, but it is quite an unrealistic level, not only for areas with night entertainment activities, particularly crowded in countries like Spain, but for almost any urban area. The noise made by people was considered by the residents as probably the most annoying night source. How can people be controlled at night in the streets? In places like Scotland inaudibility was currently used as a guideline for night time entertainment noise[21], since neighborhood noise complaints were common at noise levels of 30 dBA.

5. CONCLUSIONS

In brief, the main conclusion of this study is that the presence of an unwanted sound, perceived as aggression due to a lack of consideration, causes the appearance of effects on sleep, quiet independently of measured sound levels, which are clearly higher than the WHO recommendations in practically all points even during quiet nights. Night noise due to night life entertainment activities should be considered as a particular type of sound with specific threshold levels (probably lower than threshold levels for transportation noise) to guarantee the sleep quality of people.

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Table 1: Mean $L_{Aeq,15}$ and L_{Amax} values (dBA) in the old city and in the new city during quiet and busy nights.

		Old city	New city
$L_{Aeq,15}$	Busy nights	62.36±4.98	65.73±2.87
	Quiet nights	54.38±4.65	60.17±2.07
L_{Amax}	Busy nights	75.39±3.76	80.64±2.84
	Quiet nights	66.73±4.86	74.23±4.50

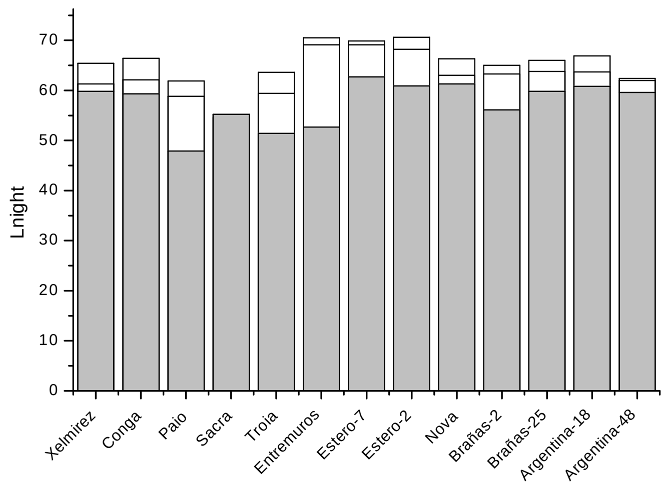

Figure 1: L_{night} values (dBA) during the two busy nights (white color) and during the quiet night (gray color) in each point.

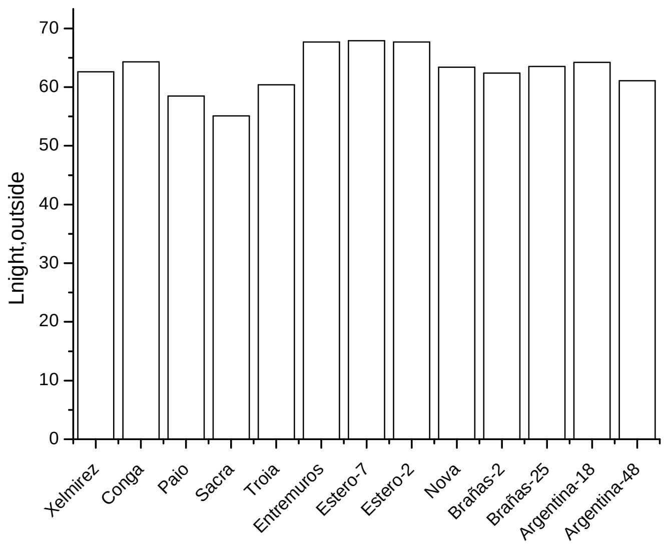

Figure 2: $L_{night,outside}$ values (dBA) in each point

Table 2: Results of the social survey

	Busy nights		Quiet nights	
	Old city	New city	Old city	New city
Annoyance rating	8.7±1.1	7.1±1.2	1.2±0.4	1.6±1.5
Difficulties	44.4%	36.4%	0%	0%
Awakenings	66.6%	45.5%	0%	7.7%

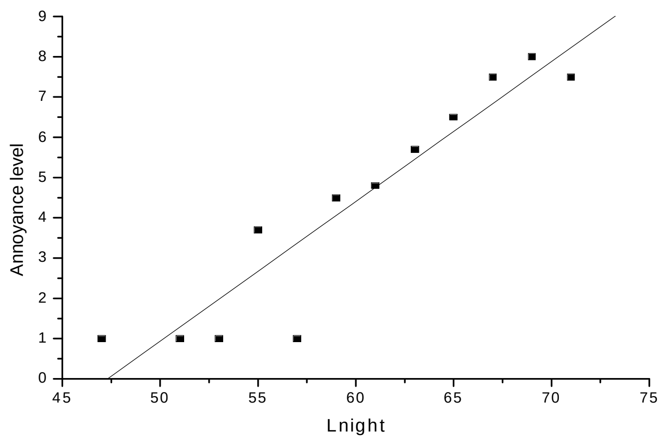

Figure 3: Correlation between annoyance ratings and L_{night} (R=0.94)

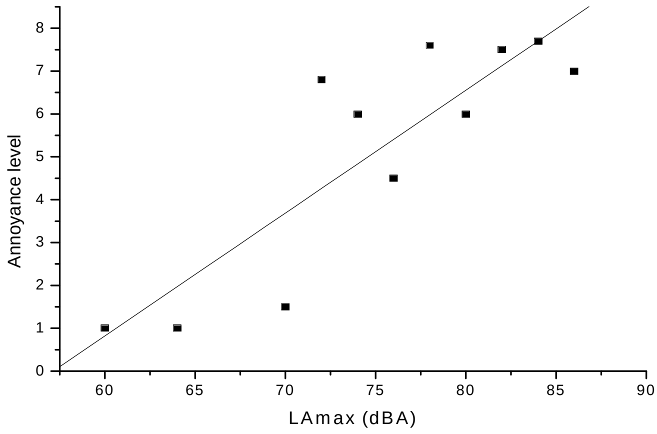

Figure 4: Correlation between annoyance ratings and L_{Amax} (R=0.86)

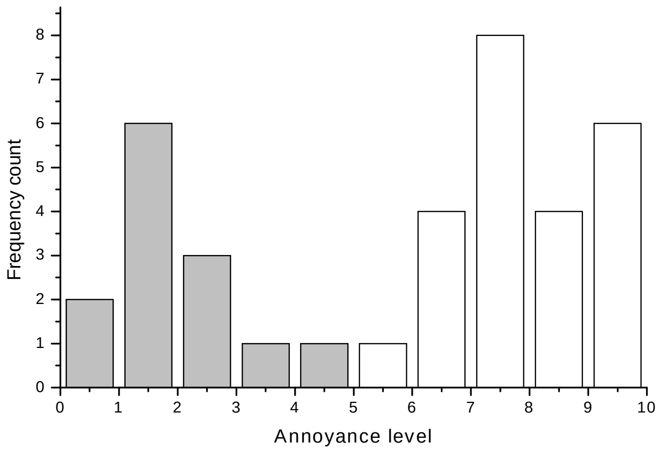

Figure 5: Distribution of the residents' annoyance ratings for busy nights (white color) and quiet nights (gray color)

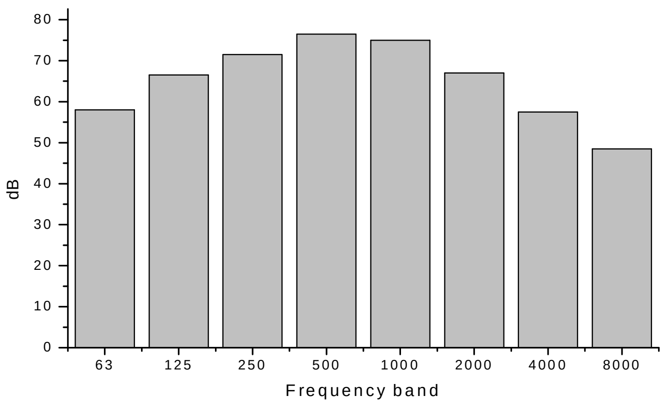

Figure 6: Noise spectrum for which the main source is the human voice

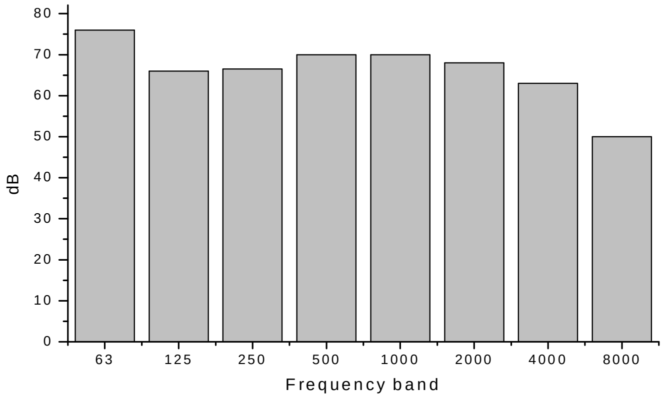

Figure 7: Noise spectrum for which the predominant source is music and traffic