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Community response to environmental noise in Granada (Spain): an evaluation by means of a standardized social survey

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ABSTRACT

Noise annoyance is one of the most important local environmental concerns nowadays reported by people living in urban areas. A standardized questionnaire designed to assess community response to environmental noise has been used in Granada (Spain) since 2005. The survey includes standardized questions and response scales that allow for comparable results with other similar studies. It pays special attention to road traffic noise and includes annoyance assessment as well as other noise effects in everyday activities. Several field campaigns were carried out in Granada coincident with the elaboration of the city second Strategic Noise Map (SNM), in order to evaluate by means of this questionnaire the effect of environmental noise on citizens and provide valuable additional information for Noise Action Planning (NAP) The sampling work was carried out by Local Agenda 21 Technical Office in collaboration with University of Granada researchers who also took part in the elaboration of Granada SNM. In this paper we present results of this survey focusing on noise annoyance rating, environmental noise effects on common activities and citizens' attitude to noise exposure. First results from a comparative study between experimental noise annoyance evaluation and dose-effect evaluation from SNM data is also included.

Keywords: Noise, Environment, Annoyance
I-INCE Classification of Subject Number: 56, 66, 76

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1. INTRODUCTION

Research on noise annoyance in Granada has been a priority since late 2004, when the first Strategic Noise Map (SNM) of the city was planned and started as a collaborative project between Granada City Council and University of Granada. UAFA research group on environmental acoustic at Applied Physics Department took this work over in 2005 and started a process that ended in 2007 with the publication of Granada first SNM (officially approved and published in 2008). A deep work estimating noise annoyance and community response to environmental noise by means of a standardized questionnaire was also undertaken, mainly following recommendations from the International Commission on the Biological Effects of Noise (ICBEN) and the Community Response to Noise team of ICBEN led by JM Fields [1,2]. The survey proved to be a valuable and reliable tool for community response to environmental noise research and it also showed that Miedema's dose-effect relationships for predicting noise annoyance from exposure metrics Lden and Lnight underestimated annoyance perceived by citizens from road traffic noise in Granada [3]. The standardized survey offered over the years a big amount of information concerning community response to environmental noise in Granada of great interest for urban planners, environment and Local Agenda 21 researchers and technicians who must elaborate Noise Action Plans (NAP).

1.1 Harmonized questionnaire

The elaboration of a harmonized questionnaire was undertaken by UAFA in parallel to SNM works, well aware of the importance of standardization in studies of noise annoyance and social surveys conducted to assess the magnitude of noise as an environmental problem. Any opinion and perception sampling had to be done according to harmonized parameters so that results and conclusions can be easily compared among similar studies carried out in other countries. A revision of community response to noise studies including noise annoyance determination was accomplished, mainly focusing on works from Schultz and Miedema on exposure-response relationships [4,5,6], recommendations from ICBEN and JM Fields [1,2] and some experiences in Spain with psychosocial studies and environmental noise surveying [7,8]. After a year-round work UAFA finally concluded the publication of "*Encuesta para la valoración de la respuesta comunitaria frente al ruido ambiental (molestia) en la ciudad de Granada*" which has been used, with minor changes, ever since in the city [9,10,11]. Latest version (in Spanish) can be downloaded from Academia [12]. The questionnaire consists of a total of 82 questions divided in six modules, covering not only noise exposure and noise effects but also other environmental aspects of everyday living, always considering outdoor noise, as shown in Table 1:

Table 1: basic structure of harmonized questionnaire for community response to noise used in Granada

Module	Content	Description	Nº questions
1	***Building***	Dwelling location, description and characteristics	**17**
2	***Environment***	Building environment description and characteristics	**13**
3	***Noise***	Assessment of annoyance and response to noise exposure, including sensitivity, stress level and auditory capacity	**27**
4	***Effects***	Effects of noise on everyday activities, including resting and sleeping	**14**
5	***Attitude***	Attitude of respondent to face and solve noise related problems at home	**5**
6	***Respondent***	Demographic variables, age, sex, education, occupational status	**6**

1.2 Survey procedure

UAFA was also responsible for the design of the survey field campaign and the realization in 2005 of a pilot study within city centre district, in order to check the quality and reliability of the questionnaire and determine the best poll process to be applied (several options were considered, including personal interviews, completed questionnaires returned by free postal mail or first-give and later come-back-to-collect, with different response rates) This research was later extended in 2006 including other city districts and then carried out over the whole city during 2007. Local Agenda 21 Technical Office helped in this participatory process from the beginning but especially in 2007 campaign with the full dissemination of the questionnaire around the city and conducting opinion poll on a personal interview basis that guarantied better response rate.

At the end of 2007 the city entered a long period (eight years) of major urban transformation because of under and over ground works from first metro line in Granada. Because of that, next SNM had to wait until urbanization works calmed down and noise surveys had to be limited or restricted accordingly. Taking this into account, research on noise annoyance was revised in one (of eight) municipal districts in 2012, not yet affected by metro line, and again over the whole city during 2015 and 2016 when the new metro line was providing its service normally. This research was, again, part of the works included in the new city SNM that was finally approved and published in 2016. As a result, all these noise annoyance surveys and community response to environmental noise field campaigns have generated a great citizens' noise perception data base covering full city and various stages of urban development. By simple random sampling technique, a number of questionnaires estimated according to population size, 95% confidence level and 5% error margin, were distributed when associated noise levels at poll sites were obtained from SNM predictions. Discretionary population sampling (DPS) technique was used for the selection of the population to be interviewed when experimental noise levels were being recorded at selected spots around the city. During last campaign in 2016, neighbourhood associations representatives helped in the distribution of the surveys around the district, so no response rate is available as the research did not started from an initial number of surveys but, on the contrary, efforts were made to receive as many surveys as possible during survey period (Table 2).

Table 2. Summarize data on community response to noise surveys in Granada. (*) 2005a extended

Year	Districts	Interview method	Response rate (%)	Surveys	Env noise levels
2005a	1	Post mail	21,4	81	Experimental
2005b	1	Personal	50,8	68	Predicted (IMMI)
2006 (*)	2	Post mail	39,2	125 (*)	Experimental
2007	6	Personal	56,8	255	Predicted (2008SNM)
2012	1	Personal	55,6	45	Predicted (2008 SNM)
2016	8	Neigh. Assoc. & Personal	-	316	Predicted (2016 SNM) & Experimental
TOTAL				**809**	

In this work we will concentrate on results from last noise annoyance survey campaign in Granada that ended in 2016, as it corresponds to a stable period in the city after metro line works finished and other major changes affecting urban soundscape, such as altered road traffic flows, new transport buses or pedestrian streets, were introduced. Associated environmental façade noise levels are coincident with questionnaire

responses, as they come from 2016 SNM and experimental recordings at selected places, so community response to noise and coincident acoustic environment are better guaranteed.

2. CONTEXT AND RESULTS

As stated above, we will concentrate on results coming from last poll campaign, starting July 2015 and ending September 2016 coincident with the finalisation of Granada second SNM. The field work was carried out on three simultaneous fronts, always counting on help and collaboration from Local Agenda 21 Technical Office and recent University of Granada graduates. The idea was to get feedback on noise effects and annoyance coming from senior residents as well as young residents, specifically university students, living all around the city but also in several selected spots where special studies were being accomplished because of some local characteristics of interest (such as new transport systems or pedestrian streets incorporated in the area) To this end, personal interviews were carried out by consultants at university spots and research areas and neighbourhood associations leaders covered the rest of the urban territory. As stated in Table 2, 316 valid questionnaires were collected in this appraisal, with respondents from districts all over the city of Granada as shown in Figure 1.

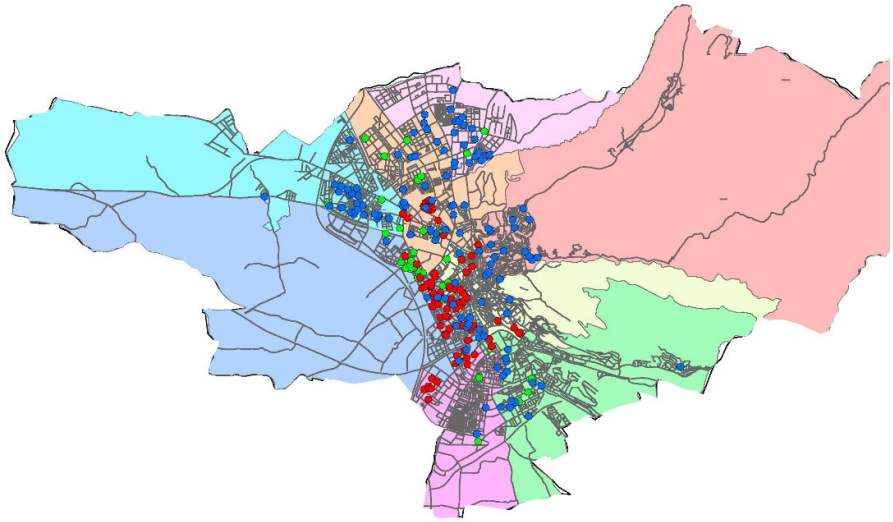

Figure 1: Location of surveys (dots) within metropolitan territory. Different terrain colour indicates the eight city districts, some including rural areas to the left and right of main urban areas.

Different dot colours in Figure 1 represent young (university students) resident responses (green), certain urban spots residents (red) and general residents in Granada (blue dots). Granada is a medium size city daily affected by a floating population from nearby towns moving in that almost double its own population. The student population taking university education count for around 20% of the population during the winter and spring time, leaving during the summer and coming back again during autumn. The total population in Granada in 2015, official census, was 235.800 inhabitants, 126.430 women (53,6%) and 109.370 men (46,4%), total amounts distributed by age as shown in Table 3.

The sample population in the survey (316 valid questionnaires) present greater percentage of respondents in the 20-34 age range than census, as shown in Figure 2. This is a consequence from intentionally having looked for university students. Half of respondents in that range (58) were interviewed at university. Few respondents lie in the

range under 19 years old, a fact that doesn't make a problem as usually children and young people pass on their relatives or friends the task. The rest of the survey sample population distribute within other age ranges in similar proportions as Granada population distribution as shown in Table 3. Women have been more active in our survey work as they overcome men participation for every age range except in the 20-34 range as shown. Nevertheless, overall participation shows similar figures according to sex as in official census, as women represent 58,2% of survey respondents against 48,2% men participation.

Table 3. Percentage sex and age distribution of total population in Granada in 2015. Official census.

	up to 19	20-34	35-49	50-64	65 and over	TOTAL
CENSUS	**43.680**	**44.444**	**51.985**	**48.108**	**47.583**	**235.800**
	18,5%	18,8%	22,0%	20,4%	20,2%	
MEN	**22.203**	**22.255**	**24.924**	**21.316**	**18.672**	**109.370**
total men %	20,3%	20,3%	22,8%	19,5%	17,1%	
census %	50,8%	50,1%	47,9%	44,3%	39,2%	46,4%
WOMEN	**21.477**	**22.189**	**27.061**	**26.792**	**28.911**	**126.430**
total women %	17,0%	17,6%	21,4%	21,2%	22,9%	
census%	49,2%	49,9%	52,1%	55,7%	60,8%	53,6%

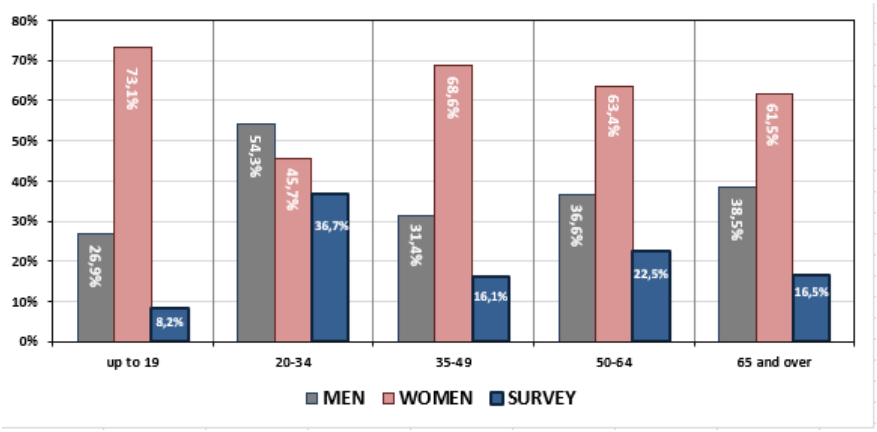

Figure 2: Sex and age percentage distribution of survey population.

2.1 The sample

As stated before, sample population in our 2015/2016 community response to environmental noise survey balances men and women participation in similar way as official census. Out of 316 valid questionnaires, 184 come from women and 132 from men respondents. Other social characteristics of survey population, such as marital status, education level and employment situation are shown in Table 4.

Table 4. Social characteristics of survey population.

MARITAL (%)		EDUCATION (%)		EMPLOYMENT (%)	
Single	48,4	No formal or Primary education	13,9	Active	28,8
Married	38,9			Unemployed	10,8
Widower	4,1	Secondary education	24,7	Pensioner	21,5
Separated	2,2			Home work	5,7
Divorced	3,2	University education degree/master	61,4	Student	31,6
Other	3,2			Other	1,6

2.2 The environment

Mean satisfaction with environment characteristics on a 0-100 scale is shown in Figure 3. It can be seen that noise is what most worries people answering our survey and they feel satisfied with municipal waste management and water quality but feel worry (under 50) about street cleaning and air quality. In fact, as Local Agenda 21 Technical Office reports, air quality and noise (day time and night time) are the two most traditionally concerned aspect of the environment in the population of Granada. Numbered as in Figure 3 from left to right, being "*Street cleaning*" number 1, "*Recycle trash containers*" number 10 and including "*Other* "as number 11, when asked about most valued characteristic, respondents place "*Street cleaning*" first as shown in Figure 4a. Clearly over the rest in second place is "*Absence of night noise*", Figure 4b, as well as second candidate to be first option. Not shown in figures, "*Air quality*, "*Absence of night noise*" and "*Solid waste management*" appear in similar weight as third option.

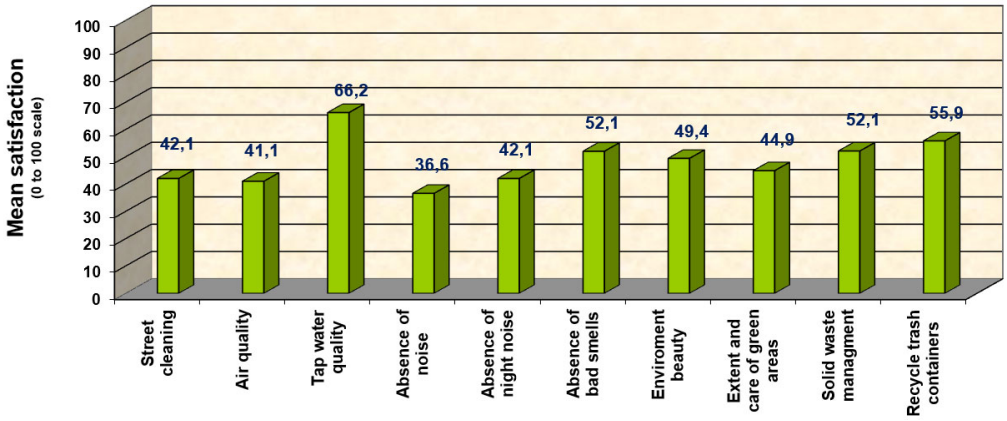

Figure 3: Survey respondents mean satisfaction with environmental characteristics

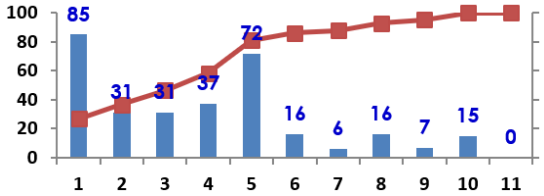

Figure 4a: Histogram first place most valued environmental characteristics (frequency %)

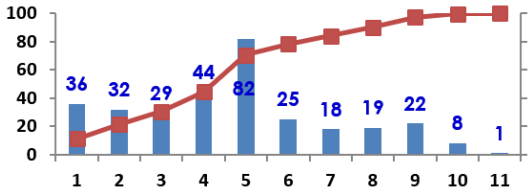

Figure 4b: Histogram second place most valued environmental characteristics (frequency %)

2.3 The annoyance

Annoyance, as most evident and direct subjective reaction to noise is, among others, itself an important human health effect. Noise annoyance assessment was the core object of this research and Module 3 of the survey give us information to clearly determined to what extent environmental noise affects residents in Granada. From previous comments, it is clear that night noise is a major concern in Granada and the absence of noise (day and night time) also valued as second option in second most valued characteristics. So, we face an important issue in the city of Granada, just like in other similar size medium size cities in the world.

When prompted to identify which urban noise source affected more severely, people clearly identified road traffic noise as the main source of discomfort, being mean annoyance 41,5 on a (0-100) scale. Noise from railroad (4,6) or aviation (7,0) are not

important in Granada, but noise from building construction (40,3) and leisure and/or commerce activities (32,8) contribute as second and third most important sources of annoyance. This is compatible with usually intense small shops trading in Granada, frequent university students around the city and construction boosted at the end of major economic crisis taking place since the end of 2015. The (0-100) numeric scale comes from the conversion of standardized verbal rating scale according to ICBEN recommendation and J.M. Fields criteria [2] as follow: "*Extremely annoyed*" (100), "*Very annoyed*" (75), "*Moderately annoyed*" (50), "*Slightly annoyed*" (25) and "*Not at all annoyed*" (0). In order to check for consistency, the same verbal rating questions on urban noise sources but under a (0-10) rating scale were included, resulting in slightly heavier importance given to traffic and quite similar results for the rest of noise sources: "*Road traffic*" (5,1), "*Railroad*" (0,8), "*Aviation*" (1,1), "*Building construction*" (4,1), "*Industrial activities*" (1,6) and "*Leisure and commerce*" (3,8).

If we focus on noise annoyance from road traffic on a (0-100) scale, respondents identify motorbikes as the main source of discomfort in Granada as shown in Figure 5. Nevertheless, cars and the rest of vehicles driving around Granada also contribute to noise annoyance, doing so in a similar magnitude rated within 12 points, from 32,4 (buses) to 44,3 (cars). The reduction of motorbikes and private cars in the city appears as something to keep in mind for noise action planning, as limiting the number of the rest of vehicles seems complicated as they mainly correspond to public services for which reduction may not be the best municipal answer.

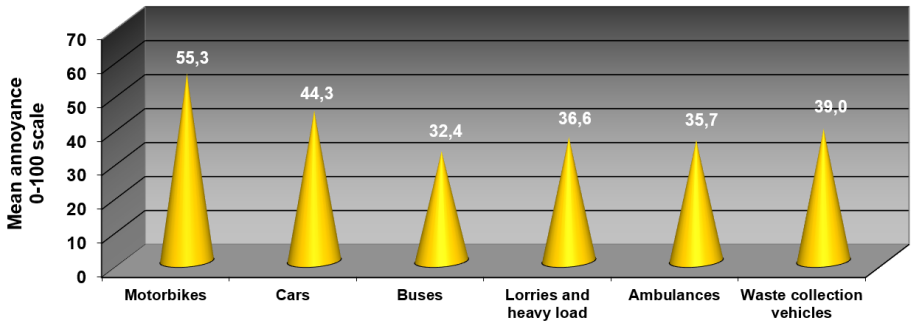

Figure 5: Mean annoyance from road traffic noise assessed on a (0-100) scale

The standardized verbal rating scale let us also estimate the percentage of people expressing "Annoyance" [%A] as sum of responses within rating scale "*Extremely annoyed*", "*Very annoyed*" and "*Moderately annoyed*" and "High Annoyance" [%HA] as the sum of "*Extremely annoyed*" and "*Very annoyed*" percentages. Considering the whole day (24h period), **51.9%** of residents in Granada reported annoyance and **22,5%** highly annoyance as shown in Figure 6. Only 19% reported absence of annoyance from environmental noise.

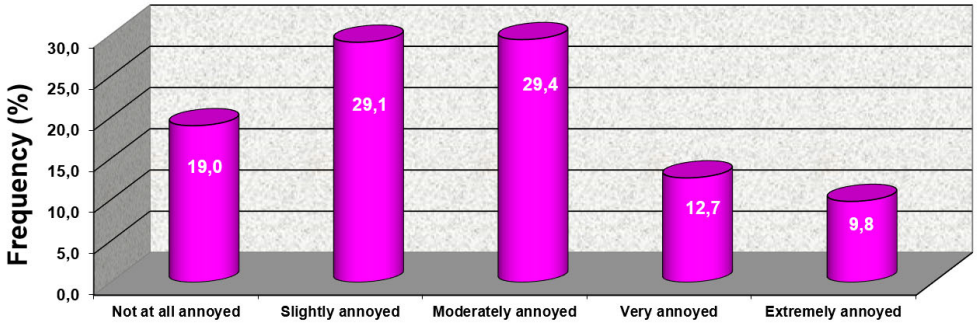

Figure 6: Frequency response on noise annoyance from road traffic noise (24h)

If we divide the 24h into *day* (from 7.00h to 19:00h), *evening* (from 19:00h to 23:00h) and *night* (from 23:00h to 07:00h) periods, we find that noise annoyance from road traffic noise is time dependent. The [%A] during *day* period stays in 51.3 %, lowering to 44,6 % during *evening* and 38,9% during *night* periods. [%HA] goes up to 25,9% during *day* period, going down to 21,5% during *evening* and 18,0% during *night* periods.

When comparing the percentage of population annoyed [%A] and highly annoyed [%HA] by noise exposure from different noise sources, road traffic noise and building construction give similar results with respect [%A] but noise from construction generates greater high annoyance rates [%HA] as shown in Table 5. If we focus on road traffic noise sources, motorbikes clearly dominate the HA urban scenario in Granada even though cars and motorbikes share similar annoyance percentages as shown in Table 6. It is also interesting to point out that the absence of annoyance (estimated by "*Not at all annoyed*" rating scale) represent 42,7% for buses, 34,8% for lorries and heavy load transports, 35,1% for ambulances and 26,3 for waste collection vehicles, but that it goes down to 13,9% and 16,5% for motorbikes and cars respectively. So noise action planning should definitely focus first on road traffic noise and, within this noise source, on motorbikes and private vehicles.

Table 5. Annoyance and High Annoyance (%) from different noise sources

	Road traffic	**Railroad**	**Aviation**	**Building construction**	**Industrial activities**	**Leisure and commerce**
[%A]	**51,9**	5,1	5,1	**49,7**	12,3	41,1
[% HA]	**22,5**	2,2	3,5	**28,8**	4,1	18,4

Table 6. Annoyance and High Annoyance (%) from different road traffic noise sources

	Motorbikes	**Cars**	**Buses**	**Lorries and heavy load**	**Ambulances**	**Waste collection vehicles**
[%A]	**66,1**	**61,7**	40,2	46,2	44,9	**50,0**
[% HA]	**47,5**	**24,1**	21,8	25,0	24,1	22,8

Self-reported information on personal capabilities and criteria for noise exposure assessment has also been carried out, giving us information on non-acoustic variables that may affect noise annoyance as shown in Figures 7a to 7e. Environmental noise levels at home sites (resident's own neighbourhood) are interpreted as lower and much lower for almost 39% of respondents, but 25,6% of answers report similar noise levels. Only 13% of respondents think environmental noise is not an important pollutant nowadays (Figure 7b) and 40,2% claims to be very or extremely very sensitive to environmental noise (Figure 7c). Self-reported high or very high stress level goes up to 33,2 % (Figure 7d) and only 6,7% claims low or very low auditory capacity (Figure 7e)

Self-reported noise sensitivity is well known to be a factor influencing subjective reaction to noise [13]. Though it has no relationship to auditory acuity, reflecting instead an evaluative predisposition towards the perception of noise [14], noise sensitivity influences non-auditory effects of noise as it increases susceptibility and, hence, moderates the reactions of individuals to noise [15]. Putting all these facts and figures together draws a usual panorama in which people find themselves as "*standard persons*", highly concerned about noise as a form of contamination, without significative audio or mental deficiencies, living in a "*standard urban area*" where noise levels are similar and just as high as in the rest of the city.

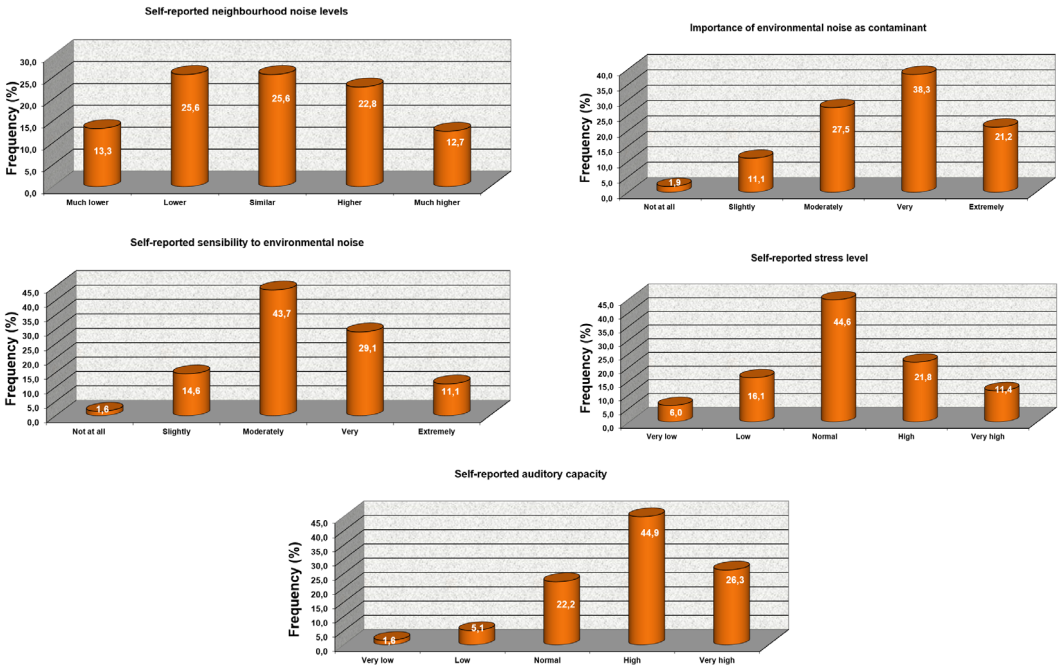

Figure 7: From left to right, top to bottom, self-reported "neighbourhood environmental noise levels" (7a), "importance of environmental noise as pollutant" (7b), "sensibility to environmental noise" (7c), "stress level" (7d) and "auditory capacity" (7e) (frequency %)

2.4 The effects

The fourth module in our harmonized questionnaire for community response to noise study in Granada, bring us information about the effects of environmental noise on everyday living, personality and performance and effects on sleep disturbance (Figure 8). Our investigation shows that environmental noise present greater overall interference on everyday activities than effects on personality/performance behaviour. Nevertheless, "*activity distraction*" get similar values as "*night sleep*" disturbance. Additional questions on night sleep effects shows that trouble sleeping at night ("*Sleeping difficulties*") is an often or very often problem in 28,8% of the cases. A small standard deviation of $\sigma \cong 1{,}2$ for all questions on a (1-5) rating scale (*1-never, 2-rarely, 3-sometimes, 4-often, 5-very often*) indicates high consensus and that noise effects are mainly conditioned by personal variables rather than by environmental circumstances, as survey population is distributed all around Granada with different environmental and soundscape circumstances.

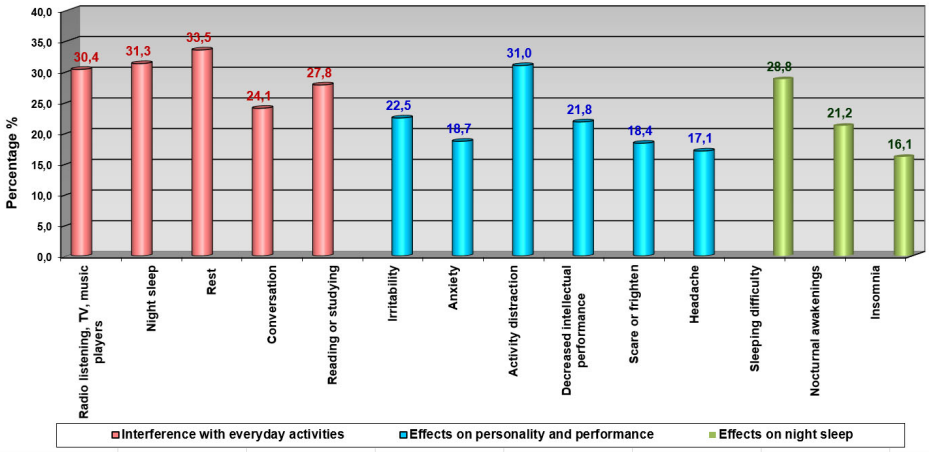

Figure 8: Percentage of respondents claiming suffering "often" or "very often" noise effects on everyday activities (pink), personality and performance (blue) and extended effects on night sleep information (green)

2.5 The attitude

The attitude towards noise is included in Module 5 of the survey. Five questions designed to give complementary information on how respondents face noise problems, what they have done or what they are willing to do in order to cope noise as a pollutant affecting their health and quality of life. Figure 9 shows that few people initiate an official actions (complaints, objections, demands) and soundproofing is still not a generalised practise. People are not willing to pay for silence but over 40% of respondents think their home has been devaluated as a result of noise. Surprisingly, few people looked for information on noise levels at home before they moved over there.

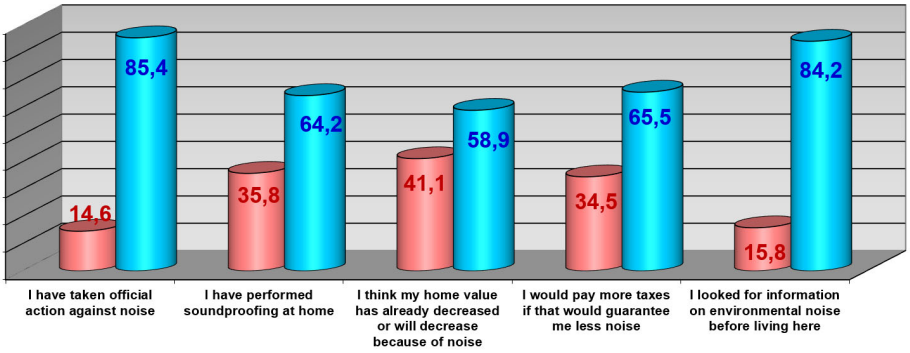

Figure 9: Participant's attitude (%) towards environmental noise (yes, red; no, blue).

3. ROAD NOISE DOSE-RESPONSE RELATIONSHIPS

The development of a good dose-response relationship has been a challenging task for years and numerous proposals can be found in bibliography to estimate annoyance from noise exposure by curve-fitting. From early synthesis studies by Shultz [4] in 1978, theoretical approaches like that from Fidel et al. [16] or works from Miedema and Oudshoorn [5], later adopted by European Commission in 2002 [6], to more recent models like that from J. Fryd and H. Petersen [17] or revised equations from WHO new environmental noise guidelines and review in 2017 [18], different dose-response and dose-effect models can be used to estimate percentages of reported annoyance and sleep disturbance from noise indicators, usually Lden for [%A] and [%HA] and Lnigh for [%SD] and [%HSD]. The lack of reliable experimental noise annoyance data has limited the number of researches on the verification of these models.

In this work, EU dose-response relationships for road noise annoyance have been used to estimate [%A] and [%HA]. These Miedema's polynomial expressions have been reported to underestimate annoyance when testing survey results versus experimental noise levels [3] or predicted noise levels from a noise map [19]. Percentages of survey population reporting "*Annoyance*" [%A] and "*High Annoyance*" [%HA] from road traffic noise have been estimated from answers to survey Module 3 by adding "*Extremely*", "*Very*" and "*Moderately*" answers to get [%A] and "*Extremely*" and "*Very*" survey answers to get [%HA]. Correspondents façade noise levels for every survey (316 valid questionnaires) have been taken from SNM 2016 database. In our research, we have used predicted noise levels from Granada second SNM finished in 2016. The main difference with our previous results [3] or that from Martin et al. [19] comes from the fact that Lden values in present research have been predicted and experimentally tested while field survey campaign was being carrying out. So, we can say that façade noise levels associated to experimental annoyance data give a good representation of what acoustic

environment was when respondents answered the questionnaire. Figure 10 show results in which theoretical approaches for [%A] and [%HA] are given by EU proposed dose-response relationships.

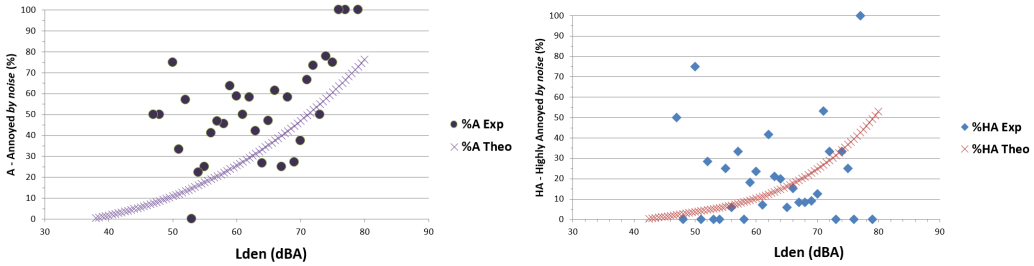

Figure 10: Experimental percentage of persons reporting annoyance (left) and high annoyance (right) to road traffic noise vs Lden (dBA) EU proposed dose-response relationship also indicated.

As it can be seen, Miedema's relationship (EU equations for road noise annoyance) keep underestimating annoyance but to a shorter extent than in previous results, confirming the importance of a good characterization of acoustic environment and, most probably, of experimental noise annoyance characterisation (survey work) This is something that needs further progress and should be only interpreted as a first approximation.

4. CONCLUSIONS

Community response to noise annoyance research has been conducted in the city of Granada by means of a harmonised questionnaire. Latest data from 2016 show the importance of road traffic noise contribution over other noise sources to noise pollution in the city and allow for a quantitative assessment in terms of annoyance and health effects from different urban noise sources. It also gives local administrators interesting information for noise action planning purposes, including annoyance estimation for the evaluation of different noise control proposals in terms of annoyance reduction.

5. ACKNOWLEDGEMENTS

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