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# Subjective Evaluation of Acoustic Quality Classes in Dwelling

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## ABSTRACT

The aim of the study was to evaluate the acoustic quality classes subjectively and compare the results with objective metrics. Interior noise level in a dwelling is described in the Regulation on Protection of Buildings Against Noise in Turkey with six classes, three of them (B, C, D classes; 35, 39, 43 dBA) was simulated via laboratory listening test experiment. 22 normal hearing participants rated the most annoying neighbor noise is determined with field study and recorded in selected household. The subjects rated three classes in terms of loudness and annoyance characteristics of the sounds. The experimental sounds were produced by loudspeakers which were installed in the same room. Calibration of interior noise level was made in the range of ±0.5 dBA. The results were statistically analyzed and subjective evaluation correlated well with interior noise level. Noise annoyance assessment differences were found between different sound types, which emphasized the importance of sound's spectrum.

Keywords: Interior Noise Level, Annoyance, Listening Test

## 1. INTRODUCTION

Acoustic comfort defines an environment where there are no unwanted sound, wanted sound have the right level and quality and acoustic activities may be performed without disturbing other people (1). Acoustic comfort evaluation can both change from one culture to another and vary at different times in the same society. The studies conducted reveal that the comfort level that people expect from life increases with the new generations (2). When aural, visual and thermal comfort parameters are studied within the context of space, it is observed that users give more importance to aural comfort conditions and that they are generally disturbed by the present situation (3).

Aural comfort is evaluated as interior noise level over sound insulation values of construction element in enclosed spaces.

The increasing use of light construction elements, starting to use sound sources with higher acoustic power and low frequency components in dwellings, new infrastructures and technical services which produce more noise than before (air conditioning systems, etc.) have brought forward the revision of sound insulation evaluation in dwellings (4). However, there are uncertainties about how the airborne or impact sound insulation will be evaluated and how the acceptable level of annoyance can be determined. Rychtarikova and Horvat (4) indicate that each country's determining its sound insulation limits values and enlarging its frequency range to comprise low frequencies is the first step. Listening tests may also be seen as the second phase to obtain more detailed information regarding the research and to find optimized solutions.

Regulation on the Protection of Buildings Against Noise (5) is in force, concerning the sound insulation to be applied in buildings in Turkey. The regulation defines limit values for 6 (A, B, C, D, E, F) acoustic performance classes. In the new buildings to be constructed, the securing of at least C class was necessitated. The values stated in the regulation were taken from the COST Action TU0901 (6) study themed "The integrating and harmonizing sound insulation aspects in sustainable urban housing constructions".

In order to meet the sound insulation requirements efficiently and effectively, there should be a high correlation between the building construction data, predicted/designed sound insulation, measured field sound insulation and the occupants' evaluation (1).

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The aim of this study is to evaluate the interior noise level subjectively which is described in the Regulation on the Protection of Buildings Against Noise (2018) via B, C, D acoustic performance classes for the dwellings. All stages of the study, social survey, noise measurements and records, the creation of sound clips, listening test and the comparison of subjective and objective data serve this purpose.

## 2. METHOD

### 2.1 Field Study

#### 2.1.1 Social survey study

The annoyance of neighborhood noise on housing users was examined through a social survey conducted with 250 people. The survey format published within the context of COST Action TU0901 (6) is taken as a reference.

In the survey, people were asked about their annoyance from airborne and impact based noise types frequently encountered in dwellings. These noises are loud speaking and shouting sound, music sound, TV sound, home appliances sound, party sound, baby cry sound, child sound, instrument sound, pet sound, door slam sound, the sounds of footsteps, moving furniture, falling objects, running children, installation sound.

In addition, the participants were asked questions about their annoyance from the internal environmental noise, the importance they give to sound insulation and how sensitive they are to noise. The question "How troubled are you with the fact that the sounds you make in your apartment are heard by your neighbors?" that is not included in the reference survey was also added to the study.

11-point numerical scale was used in all questions as described in the ISO / TS 15666:2003 (7) standard and descriptive verbal statements (i am not disturbed, i am very disturbed, it does not matter at all, it matters a lot etc.) and pictograms were included at the endpoints of the scale.

In the next stage of the study, which included interior noise level comparisons, the noise types to be listened to by the participants were determined according to survey results.

#### 2.1.2 Noise measurement and recording

According to the participants' responses, first most annoying 3 airborne noises was measured and recorded. The living space with an open kitchen plan diagram of 4.5 m x 4.3 m in dimensions and 2.6 m in height was chosen as a reference dwelling. In the dwelling, reverberation time (T) measurement was made in accordance with the TS EN ISO 3382-2:2013 (8) standard and a 24 hour $L_{gag}$ measurement was made in accordance with the TS ISO 1996-2:2009 (9) standard. Stereo sound recordings were taken at a distance of 1 m from the determined noise sources, also $L_{Aeq}$, $L_{AF,max}$ measurements done synchronously. The measurements were made using the dual-channel 'Brüel & Kjaer Type 2260 sound level meter', 'TASCAM DR-05' stereo audio recorder is used for sound recordings, 'Qualifier 7830' and 'Noise Explorer' software for evaluation and reporting purposes.

### 2.2 Laboratory Study

#### 2.2.1 Creating sound clips

The sound recordings of the noise source received in the reference house were transferred to the computer in '.wav' format. In the social survey study, the 3 most disturbing airborne noises (loud sound and shouting sound, installation sound, child sound) among the 15 noise sources were used for the subjective evaluation of the interior noise. These three noises were arranged in accordance with the 35 dBA (Class B), 39 dBA (Class C) and 43 dBA (Class D) sound levels defined as the highest noise level allowed in space in Adobe Audition program, Regulation on the Protection of Buildings Against Noise (2017), depending on acoustic performance classes. A total of 9 stimuli were formed for 3 noise types and 3 separate classes each with a length of 1 min.

#### 2.2.2 Listening test

The listening test was conducted in a soundproofed laboratory with the jury. According to the results of the hearing tests performed before the listening test, 22 people whose hearings were on bilateral normal borders were included in this study.

The participants first evaluated 9 sounds in terms of sound level. People were asked to imagine that they were on their own apartments, in silence and peace. They were expected to evaluate the level of sound they heard with a scale of '0 to 10', expressed in numbers and words, considering the moment when they started to hear a sound from the neighboring house at a time when they were resting (0 - not high at all; 10 - extremely high).

Afterwards, they were asked to imagine the same scenario in the first chapter and to assess the annoyance level of the sound they heard (0-not annoying at all; 10-extremely annoying). They were expected to read and understand the following 3 sentences and answer the 5 correct / false statements, concerning these sentences, on the back page. Finally, they were asked to assess how annoying the sound they were listening to was in the phases of reading- comprehension, retention and inference of sentences.

In this section, the jury listened to a total of 18 stimuli in '.wav' format, each piece being 1 minute long and leaving 30 second gaps between sounds. The jury was made listen to 3 different playlists prepared in Windows Media Player randomly.

The stimuli were produced by means of 2 speakers. Mackie CR4 BT brand 1 active, 1 passive studio reference monitor was used. In the listening test, photographs of the housing environment were shown, in order to help the person to imagine the home environment.

## 3. RESULTS

### 3.1 Social Survey Results

A total of 250 people, 138 of whom were female, 110 male and 2 unresponsive participated in the survey. The majority of the participants (77.3%) are between the ages of 18-39 and the participants over the age of 40 constitute approximately 22.7% of the total. Of the participants, 92 (38.8%) are married, 145 (61.2%) single, and 68.7% work during daylight hours. Only 27.8% have been living in the residence for less than one year and 82.3% of the participants are in the range of 2-4 persons of the household size. The statistical reliability of the 19 questions was 91.8% according to Cronbach's Alpha value.

The annoyance order of noise types evaluated based on their arithmetic means. Table 1 shows that the annoyance degree of noises according to the participants is loud speech and shouting sound, installation sounds and child running sound. The most annoying airborne noise is loud speech and shouting sound; the most annoying noise caused by impact is the child running sound and the most annoying air and impact borne noise is the sound of home appliances.

Table 1 – Evaluation of noise types in terms of annoyance with 11-point Likert scale (0-10).

| degree | noise | type of noise | N | mean | median | standard deviation |
|---|---|---|---|---|---|---|
| **1.** | Loud speech and shouting | airborne | 244 | 5,42 | 5 | 3,215 |
| **2.** | Installation sound | airborne | 235 | 4,51 | 4 | 3,468 |
| **3.** | Running children sound | impact | 234 | 4,43 | 4 | 3,611 |
| **4.** | Door slam sound | impact | 234 | 4,39 | 4 | 3,387 |
| **5.** | Moving furniture sound | impact | 233 | 4,12 | 3 | 3,502 |
| **6.** | Falling object sound | impact | 233 | 4,03 | 3 | 3,331 |
| **7.** | Child sound | airborne | 230 | 3,88 | 3 | 3,469 |
| **8.** | Footstep sound | impact | 237 | 3,82 | 3 | 3,424 |
| **9.** | Home appliances sound | airborne+impact | 227 | 3,69 | 3 | 3,085 |
| **10.** | TV sound | airborne | 233 | 3,36 | 3 | 2,955 |
| **11.** | Baby cry | airborne | 229 | 3,31 | 2 | 3,504 |
| **12.** | Music sound | airborne | 241 | 3,15 | 2 | 3,000 |
| **13.** | Party sound | airborne+impact | 218 | 2,63 | 1 | 3,307 |
| **14.** | Instrument sound | airborne | 226 | 2,24 | 1 | 2,984 |
| **15.** | Pet sound | airborne | 225 | 2,02 | 0 | 2,888 |

When Figure 1 is studied, it is observed that 42.7% of the participants are very annoyed or exceedingly annoyed when the annoyance from internal environmental noise is evaluated, considering the last 12 months. It is observed that 43.2% of the participants are very annoyed or exceedingly annoyed by hearing their own sound from the neighbor, while 42.9% of them are not annoyed or are slightly annoyed. Considering the responses to the request "Evaluate the importance of sound insulation for you when you consider the internal environmental noises (neighborhood noises, mechanical devices, etc.)", it is observed that 72% of the participants give importance or great importance to sound insulation. Regarding the question "How sensitive are you to internal environmental noises?, it was found that 54% of the participants considered themselves sensitive or overly sensitive while 22% considered themselves not sensitive at all or not sensitive. In percental dispersions, 0-2 range was evaluated as 'i'm not annoyed', 3-4 range as 'i'm a little annoyed', 5-6 range as 'i'm moderately annoyed', 7-8 range as 'i'm too annoyed' and 9-10 range as "i'm extremely annoyed."


Figure 1 – Percentage distribution of answers

### 3.2 Listening Test Results

Of the participants in the listening test, 68.2% were female, 31.8% were male and the average age of the 22 subjects was 31.55. 68.2% of the jury stated that they are tenants in the dwelling they live in and 31.8% of them stated that they own the property. The average residence time of the participants was 4.64 years, the number of floors in the building they live in was 8.68 and the average time they spend in their apartment was 12.36 hours. The statistical reliability of the listening test was 87.4% according to Cronbach's Alpha value.

22 juries evaluated totally 9 interior noises at 35, 39, 43 dBA levels appropriate for 3 acoustic performance classes (B,C,D class) for 3 noise types (loud speech, child, installation sound). The scattering diagrams showing the change of the interior noise evaluation means according to the interior noise levels are given in Figure 2. The participants evaluated the same sound in terms of the sound level and the annoyance it gives while resting and while studying. Besides, the annoyance evaluation mean and interior noise level graphics obtained by averaging the annoyance while resting and studying were also included. The average number of correct answers given by the participants to the 5 correct/false propositions about the 3 sentences they read is also expressed in response to interior noise levels.

Data were analyzed in 95% confidence interval by linear regression analysis. 90% of the change in interior noise level can be explained by loud speech, 99.5% by child and 99.7% by installation sound, sound level evaluation. 8% of the change in interior noise level can be explained by loud speech, 98.9% by child and 76.4% by installation sound annoyance evaluation mean. In addition, 48% of the change in interior noise level can be explained by loud speech, 94% by child and 38% by installation sound average number of correct answers.

When the data of the interior noise level regarding sound level and annoyance assessment averages are examined together, it is observed that it has positive correlation with both variables (Figure 3). Increased interior noise level has also led to an increase in sound level and annoyance assessment. Although they were at the same noise level, the volume of children's sound, loud speech and installation sound (from big to small) did not change in sound level or annoyance evaluation.

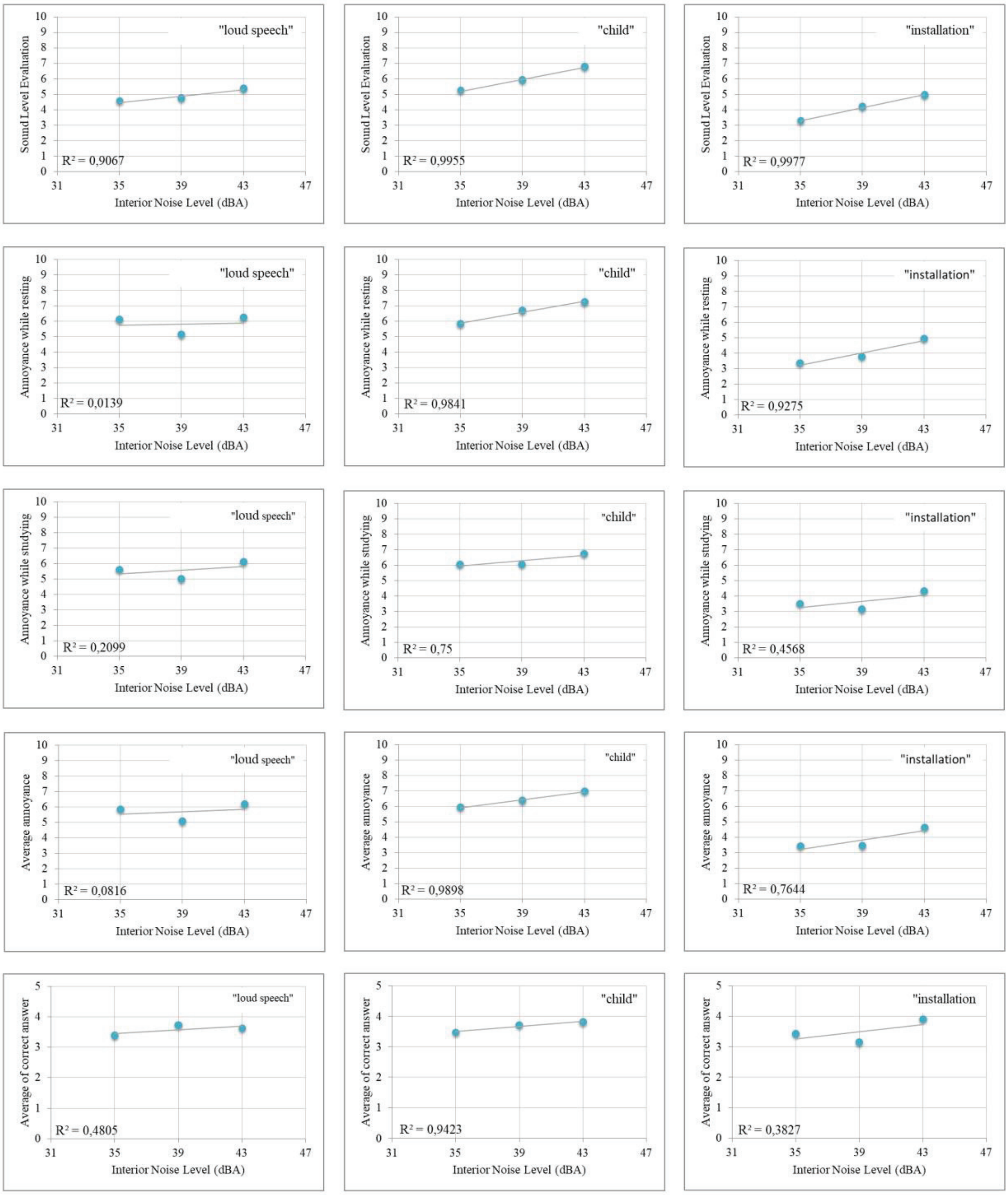
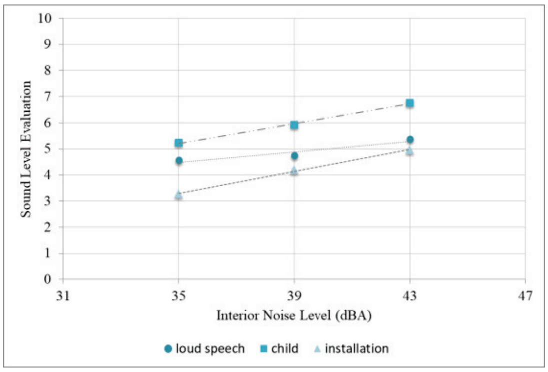



Figure 2 – Linear regression analysis

When the correlation of dependent variables is examined, it is observed that there are very high correlations between sound level evaluation and annoyance while resting ($r=0.871$, $p=0.000$) and between annoyance while resting evaluation and annoyance while studying evaluation ($r=0.887$, $p=0.000$); and there is a high correlation between sound level evaluation and annoyance while resting evaluation ($r=0.767$, $p=0.000$). It is also read that no correlation is formed between the number of correct answers and sound level evaluation, annoyance while resting or studying ($p>0.05$).



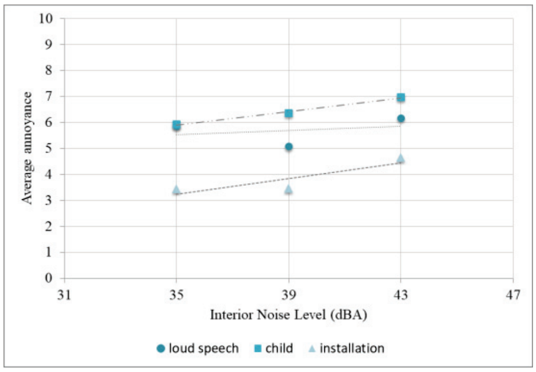




Figure 3 – Linear regression analysis for three noise

## 4. CONCLUSİON

In the social survey study conducted with 250 people, it was observed that the society tends to be mostly annoyed by loud speech and shouting sound, installation sounds and child running sound. Sounds of loud speech and shouting, installation and children were evaluated as being more annoying airborne noise than others. The number of samples should be increased in order to obtain the profile of the annoyance of the neighborhood noise of Turkish society.

An examination of the results of the interior noise assessment of the listening test shows that loud speech, child and installation sounds are evaluated differently although they are at the same noise level. The difference stems from the sound's spectrum discrepancy. The sounds contains high frequency components create a higher sound level perception and people have higher tolerances for lower frequencies. It is seen that the definition of regulation values only from the interior noise level does not fully reflect the diversity of sound encountered in daily life. which emphasized the importance of sound's spectrum.

When the annoyance while resting evaluations of 3 types of noise were examined with 5-part division, it was observed that the jury evaluated 51.53% of class B, 53.06% of class C and 72.73% of class D as annoying or exceedingly annoying. In literature studies (10) it is stated that this ratio should be less than 10% or equal to at least 20%. That the ratios are far above the norm, may stem from the usage of the mostly disturbed noise types. It is also thought that the majority of the jury profile's being composed of sensitive to noise persons is effective. For more comprehensive assessments, the proposed method should be applied on larger populations, and it should be researched to what extent the regulation values taken from COST Action TU0901 (6) study reflect Turkish population's noise annoyance perception.

**Future studies**

Future researches can explore more noise types through holistic approaches in which the impact and airborne sound insulation are discussed together with the methodology used in this study. Although laboratory conditions simulate the home environment, it does not give the same result. For this reason, the practice of similar studies in the dwellings of the individuals, in the conditions in which their relations with their actual neighbors are also considered, may give interesting results.

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