Classification of Heavy-weight Floor Impact Sounds Based on Perceptual Noise Levels and Annoyance

Sung Min Kim, Joo Young Hong, Jin Yong Jeon
Department of Architectural Engineering, Hanyang University, 133-791 Seoul, Republic of Korea.

Summary
The current subjective system of classifying floor impact sound levels is insufficient and requires more accurate classification criteria Statements describing floor impact sound are collected and used to create a new statement-based scale using the equal-appearing interval scale method. An auditory experiment was conducted measuring annoyance levels and using the new statement scale to establish a floor impact noise standard in apartment buildings. Floor impact sounds from impact ball were recorded; the impact sound pressure level (SPL) and the temporal decay rate (DR) were analyzed. For the experiment, A-weighted exposure levels of the heavyweight floor impact sounds ranging from 34 to 73 dB were evaluated at 3 dB intervals. Participants used a 7-point verbal scale (annoyance level) and the new 7-pt statement scale. Consequently, a floor impact sound classification based on response statement was proposed

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1. Introduction

Floor impact sounds are one of the most annoying noises in apartment buildings. In particular, heavy-weight impact sounds, generated from adults walking or children running and jumping, are the source of many of complaints. Several floor impact sound studies have been conducted to solve this problem.
Usually, the loudness of the impact noise, affected by the maximum sound pressure level (L_{Amax}), is the most critical factor affecting perception of noise. [1-3] However if the sound pressure level is the same, subjective responses to floor impact sounds can still differ. Kim et al. [3] discovered that the sound pressure level and the temporal decay rate of floor impact sounds significantly influence annoyance perception. A few studies to classify the floor impact noise levels based on annoyance level have been performed taking into account both sound pressure level and temporal decay rate. Also, the floor impact sound classification standard in Korea rarely considered apartment building residents opinions about floor impact sound. In particular, there is a considerable need for new criteria for accurately evaluating subjective responses

In this study, two kinds of test were performed. The first test was scaling new evaluation standard for floor impact sound based on residents' verbal responses using an equal-appearing interval scale method. The other test was performed to evaluate variation of sound pressure level and temporal decay rates with annoyance and the newly defined statement-based standard.

2. Equal interval scale

To understand apartment resident response to floor impact sound, new evaluation criteria for floor impact sound that excludes the annoyance attributable to the noise are necessary. The new standard based on occupants' attitude and response of floor impact sound with equal-appearing interval method.

2.1 Method

Thirty-three statements were collected from the Department of Environment and departments related to noise and environment. These statements represent resident feedback about floor impact noise. Some statements are given as examples in Table I. a total of fifty subjects participated in the survey and each subjects ranked each statement on

Table I. Examples of the collected statements

No.	Statement
1	The indoor environment is quiet.
2	It is as if there is no one living upstairs.
3	Noise can't be heard.
4	Live a pleasant life.
5	It is possible to concentrate on things.
6	I can take a nap.
7	It does not bother me.
8	I do not worry about floor-to-floor noise.
9	It is possible to live without being aware of the upstairs neighbors
10	If you have patience, problems can be handled.
11	In any case, complaints do not occur.
12	I go upstairs to complain to the neighbors.
13	Seriously contemplate sound proofing your home.
14	I get angry because of the noise.

a 7-point scale ranging from "1: Not annoyed" to "7: Extremely annoyed". [4] Based on the survey's results, we calculated the median value and interquartile range for each statement. If the median values of several statements were similar, we chose the most appropriate statement with the shortest interquartile range.

2.2 Results

The results of the survey and equal interval method allowed us to determine the statements

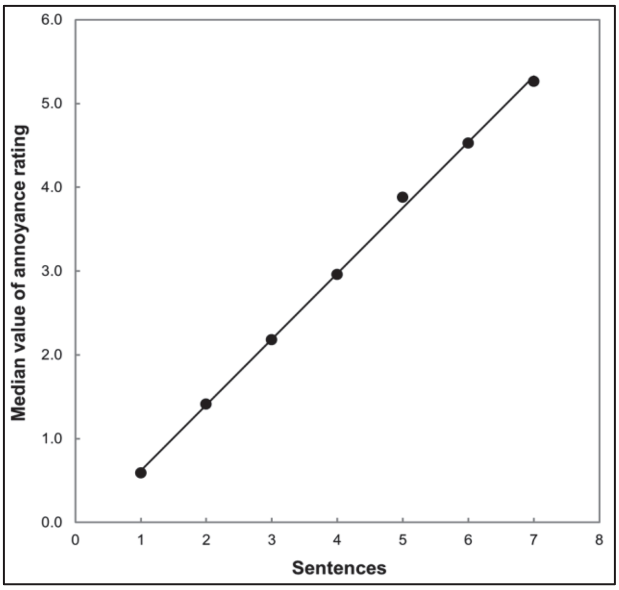

Figure 1. 7-point floor impact sound statements.

Table II. Selected 7 floor impact sound statements

No.	Value	Statement
1	0.6	The indoor environment is quiet.
2	1.4	It does not bother me.
3	2.2	If you have patience, problems can be handled.
4	3.0	Need to be considerate about each other.
5	3.9	Noise disturbs my relaxation time.
6	4.5	Indoor conversations cannot be heard.
7	5.3	It is impossible for people to live here.

most representative of resident rating for this new statement-based scale. This scale forms the proposed criteria for floor impact noise. Figure 1 shows that the new standard consists of 7 selected statements which have almost equal intervals. The 7 selected statements are shown in Table II.

3. Classification of floor impact sound

3.1 Experimental design

Noise annoyance and subjective responses for heavy-weight floor impact sounds were investigated with auditory experiment conducted under laboratory conditions. Acoustic stimuli were created by recording heavy-weight impact sounds in apartment buildings with a box-framed type reinforced concrete structure using a spectrum type II rubber ball [5]. The impact sound was recorded in the center of the room using a ½ inch microphone (B&K type 4189) and a head and torso simulator (HATS, B&K type 4100).

Two factors affecting perception of heavy-weight floor impact sounds were taken into account: sound pressure levels and decay rates. L_{Amax} of acoustic stimuli was varied from 34 to 73 in 3 dBA intervals [6]. The decay rate (DR) was used to quantify the temporal decay of impact sounds. DRs of the stimuli were set at 30 and 60 dB/s, because more than 70% of the ball sound DRs were between 30 and 60 dB/s [3]. In total, 28 stimuli were created. The stimuli were presented to subjects in a random order, with 5s intervals between them.

Noise annoyance was assessed using a 7-point verbal scale (0: not at all, 1: insignificantly, 2: somewhat, 3: moderately, 4: considerably 5: highly, 6: extremely) by asking following question: "How much do you annoying, if you imagine that you were exposed to it in the living room?" Experiment subjects assessed their noise annoyance level using 7 selected statements shown in Table II. Subjects chose the statements that most accurately represent their attitude after hearing the sounds.

3.2 Procedure

Thirty subjects in their 20s and 30s participated in the experiment. Before the experiment, all participants had their hearing threshold level tested with an audiometer (Rion AA-77). The tests demonstrated that all participants had normal hearing. The experiments were performed in a testing booth with a low background noise of approximately 25 dBA (LAeq), and the sound stimuli were presented using headphones (Sennheiser HD-650). A high-pass filter and a low-pass filter, in which the cut-off frequency was 63 Hz in the octave band, were applied to the sounds reproduced by the headphones.

3.3 Results

Figure 2 shows the percentage of annoyed subjects who gave a rating '3: moderately' or higher on the 7-point scale (%A) as a function of L_{Amax} for each DR. Except at the 0 ~ 10% and 90 ~ 100% level, almost 10% interval differences are visible from 40 dBA to 65 dBA. Also DR30 results in a higher annoyance percentage that DR60 in across the whole sound pressure level. Table III describes the classification of annoyance for heavy-weight floor impact sounds based on dose-response curve of %A. Annoyance levels were divided into 5 classes each a 20% interval of %A except class A and class E, which each have 10% to make each class's SPL interval equal. The highest and lowest 10% intervals were considered irrelevant because people in those levels either felt obviously annoyed or not annoyed. That is, their responses were not clearly dependent on the variables studied. Class A indicates that for less than 20% annoyance, more than 10% subjects evaluated the lower dBA/DR stimuli as not annoying, while class E indicates more than 80% of subjects evaluated the stimuli as higher dBA/DR stimuli as annoying. Figure 3 shows the mean value of statement scale. Class A can be considered a "good" noise condition, while Class E can be considered a "bad" condition.

Table III. Classification of annoyacne for heavy weight impact sound

Class	*%A*	*L_{Amax} [dBA]*		
		DR30	*DR60*	*Total*
A	10 – 20%	< 42.0	< 47.0	< 44.5
B	20 – 40%	< 47.5	< 52.5	< 50.0
C	40 – 60%	< 52.5	< 57.5	< 55.0
D	60 – 80%	< 58.0	< 64.0	< 61.0
E	80 – 90%	< 62.0	< 68.0	< 65.0

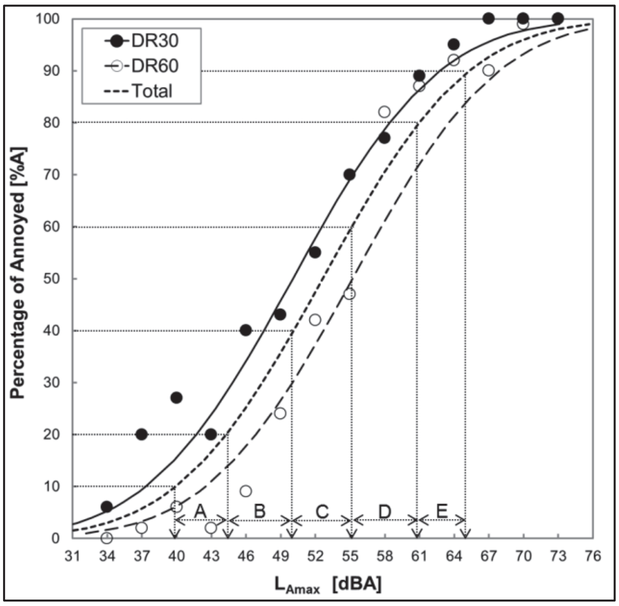

Figure 2. Percentage of annoyed subjects

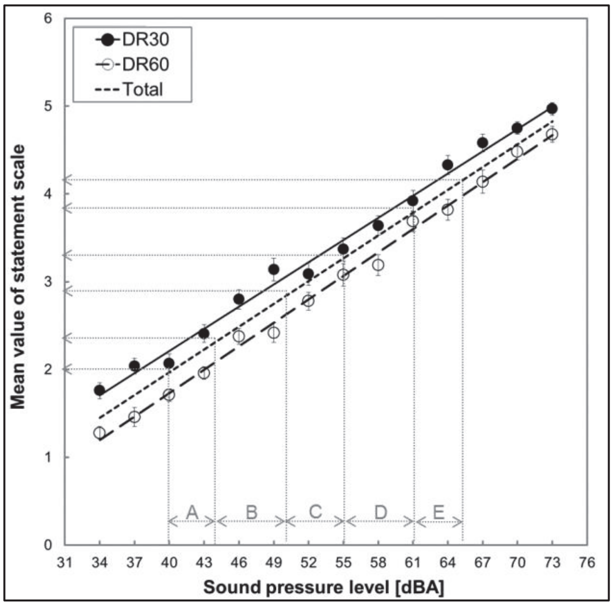

Figure 3. Mean value of statement scale

Table IV. Classification of resident's responses for heavy weight impact sound

Class	*Scale value*	*Statement*
A	2.0 – 2.2	It is possible to live without being aware of the upstairs neighbors.
		If you have patience, problems can be handled.
B	2.2 – 2.8	In any case, complaints do not occur.
		It is possible to read indoors.
C	2.8 – 3.2	I am sometimes aware of my upstairs neighbors.
		It is okay if the upstairs neighbours provide us with compensation.
D	3.2 – 3.8	I am frequently aware of my upstairs neighbours.
		The noise from upstairs can be heard clearly.
E	3.8 – 4.1	Noise disturbs my relaxation time.

In general, the mean statement value increased as L_{Amax} of stimuli increased. This result indicates that the residents perceived a louder floor impact sound, their response with statements representing greater annoyance. Figure 2 and 3 results resulted from the same stimuli; thus, matching %A with the statement scale using the 5 classes's L_{Amax} intervals from Table III is possible.
Table IV shows the appropriate statements in each of the 5 classes based on L_{Amax} intervals from Figure 2. Class A indicates that 10 ~ 20% of %A is matches the new statement scale value 2.0 – 2.2, and statements which have scale value from 2.0 to 2.2 can more accurately represent the resident's evaluation of floor impact sound.

4. Conclusion

In this study, a new set of statement-based criteria for classifying noise annoyance levels resulting from heavy-weight floor impacts was evaluated. These criteria were evaluated as a function of both L_{Amax} and DR in controlled laboratory tests. People feel more annoyed when the sound pressure level of the noise increased and the DR of floor impact sound decreased. The controlled experiments conducted in this study suggests heavy-weight impact sound and subject's responses can be related by the 5 defined classes.

Acknowledgement

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