Psychoacoustic studies on the evaluation of impact sound of lightweight stairs

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Introduction

Impact sound measurements of lightweight stairs often show a lack of correspondence between the evaluation according to the standards and the hearing impressions of the inhabitants. As a consequence actual measuring and rating procedures seem not to be suitable to avoid annoyance. To improve this situation and derive evaluation methods closer to the subjective impressions, first psychoacoustical studies were made, in addition to physical investigations already presented at earlier DAGA conferences [1,2,3]. Several walking noises on different lightweight stairs were investigated, also different artificial impact sound sources were measured. A listening test with 21 persons as a preliminary investigation was conducted. Furthermore psychoacoustic quantities of human walking and jumping were measured and compared. The intention is to find the important psychoacoustic parameters to characterise walking and the most appropriate impact sound source to represent impact sound of real walkers.

Method

The impact sounds were recorded in the receiving room as two-channel measurements using a dummy head. The walking noises were generated by a total of eight persons with different footwear. Four men and four women. Five different lightweight stairs were investigated, they are listed and described in Table 1.

S 1	Straight stair with solid timber steps, construction supported by the banister, steps mounted with steel bolts in the partition wall. Partition wall: CaSi, d = 24 cm
S 2	Straight stair like S 1, but with elastic coverings over the steel bolts. Partition wall: CaSi, d = 24 cm
S 3	Straight stair like S 2, but with wooden stringer at the wall side. Stringer fixed at partition wall Partition wall: CaSi, d = 24 cm
S 4	Like S 2 but with two quarter turns. Partition wall: double leaf, aac, 2 x 17.5 cm
S 5	Metal staircase with two quarter turns and timber steps. Elastic layers between the mounting and the partition wall. Partition wall: double leaf, aac, 2 x 17.5 cm

Table 1: Different lightweight stairs

The artificial impact sources used were the standard tapping machine, the modified tapping machine and a rubber ball according to ISO/CD 140-11. The dummy head recordings of three stairs (S 1, S 2, S 3) were performed at a laboratory for staircases [4], the recordings of the other two stairs (S 4, S 5) took place in an inhabited terraced house. Inside the terraced house only the impact sounds of walking of two persons were recorded. The recordings were analysed with a psychoacoustics analysis software that calculated the psychoacoustic parameters loudness (according to Zwicker), fluctuation strength, roughness (in accordance with Aures) and sharpness.

Walking

When calculating the psychoacoustic parameters significant differences were found for loudness, fluctuation strength and roughness, depending on footwear and construction. The sharpness value for all recorded impact sounds of walking on different staircases was around 1 acum. As a consequence sharpness seems not to be an important psychoacoustic parameter to characterise walking.

Investigations of the sound pressure levels of different impact sounds of walking on S 2 [2] had shown that the greatest differences were caused by footwear. For the psychacoustic studies eleven different impact sounds of walking on the stairs S 1 and S 2 were analysed. The footwear of the walking persons was divided into three groups: high heeled shoes with hard heels (n = 4), low shoes with rubber or leather sole (n = 4) and hiking boots (n = 3). For each group the mean values of the psychoacoustic parameters were calculated. To find similarities correlation coefficients (according to Bravais-Pearson) between these mean values and all walking noises were computed. The results for the specific loudness on S 2 are shown in Figure 1.

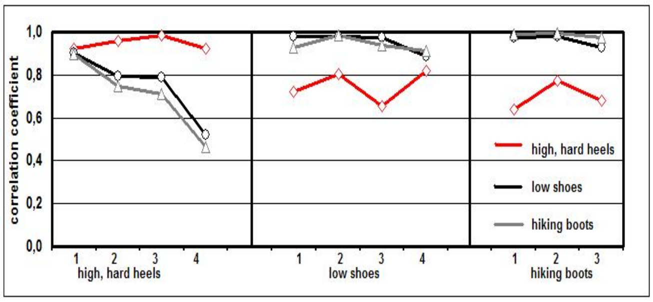

Figure 1: Correlation coefficients for specific loudness between mean values of footwear groups and eleven different impact sounds of walking (4 with high heels, 4 with low shoes, 3 with hiking boots) on S 2

There is a good correlation between impact sounds of walking with low shoes and hiking boots. The biggest differences are caused by high heeled shoes with hard heels. The correlation coefficients for specific roughness and specific fluctuation strength show the same tendency. The same on lightweight stair S 1. On the other stairs only four (S 4, S 5) or five (S 3) impact sounds of walking were recorded and no relevant different groups could be built.

Impact sources

Impact sounds of the artificial impact sources were recorded on all stairs. To compare these impact sounds with impact sounds of different walking noises, correlation coefficients were calculated. The results for specific loudness on the stairs S 2 and S 1 are shown in Figures 2 and 3.

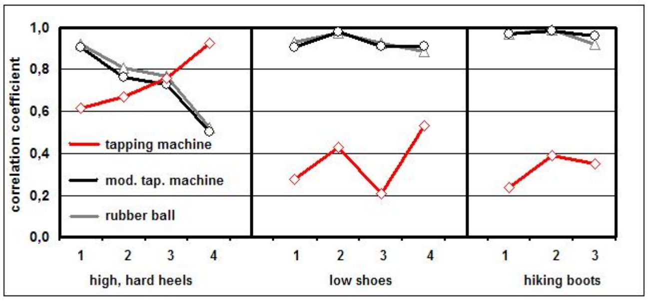

Figure 2: Correlation coefficients for specific loudness between impact sounds of artificial impact sources and 11 different walking noises on S 2

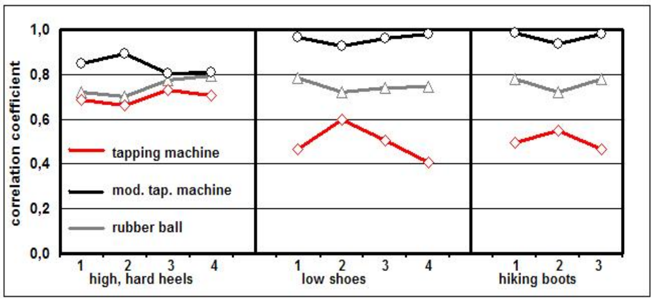

Figure 3: Correlation coefficients for specific loudness between impact sounds of artificial impact sources and 11 different walking noises on S 1

The impact sound of the standard tapping machine has a high correlation with walking on high heeled shoes. Impact sounds of modified tapping machine and rubber ball show high and very high correlations with impact sounds of most walking noises. The calculated correlation coefficients between impact sounds of three artificial impact sources and walking considering all impact sounds of walking on all stairs are listed in Table 2.

	tapping machine	mod. tapping machine	rubber ball
specific loudness	0.68	**0.96**	0.94
specific fluc. strength	-0.12	0.64	**0.74**
specific roughness	0.38	**0.68**	0.58

Table 2: Correlation coefficients for psychacoustic parameters between artificial impact sources and all walking noises

Listening test

A listening test with 21 persons, 8 women, 13 men as a preliminary investigation was conducted. The subjects were listening to recorded impact sounds using headphones. Nine recordings from stair S 2 were used, among them six different impact sounds of walking and three impact sounds of standard tapping machine, modified tapping machine and rubber ball. The subjects had to find verbal expressions for their hearing impressions. To reduce data and find groups factor analysis was used. Two main components were extracted and two main groups were found. Component 1 (variance 49.7%) with the adjectives muffled (german: dumpf) and deep. High loadings on component 1 had five impact sounds of walking and the impact sound of the rubber ball. Component 2 (variance 17.7%) with the adjectives loud, wooden, high, hard and hammering. High loadings on component 2 had the impact sound of the standard tapping machine and impact sound of walking on high heeled shoes. Component 1 describes the low frequency content of the impact sounds. Component 2 could be approximated by loudness and roughness. The psychoacoustic parameters of the used recordings were analysed and for specific roughness and specific loudness a high correlation between the impact sounds of standard tapping machine and walking on high heeled shoes was found.

Summary and outlook

The main hearing impressions of impact sounds of walking on lightweight stairs are loudness, roughness and fluctuation strength. The biggest differences are caused by footwear, especially by high heeled shoes with hard heels and by different staircase constructions. Because of the differences caused by footwear a characteristic impact sound of walking could not be found. Modified tapping machine and rubber ball are useful to characterise the specific loudness of different impact sounds of walking. The standard tapping machine could just characterise specific loudness and specific roughness of impact sound of walking on high heeled shoes.

To find evaluation methods closer to the subjective impressions it is important to know, if it is sufficient for an artificial impact source to get close to the specific loudness of impact sound of real walking or if it is necessary to consider roughness and fluctuation strength as well. Listening test will be necessary to find the main parameters of annoyance of impact sounds of walking. Knowing these parameters it might be possible to create an “annoyance index” for the evaluation of lightweight stairs.

References

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