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Recent progress in the field of community response to noise

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ABSTRACT

This paper aims to review the progress within the field of the community response to noise and noise annoyance based on peer-reviewed publications in the past three years (2014 to 2017). Developments include an increased focus on local or case-specific as opposed to generalized exposure-response relationships to predict noise annoyance, as well as a renewed interest in the influence of temporal and spectral characteristics on the annoyance at a given noise level. In addition, new research has been published on annoyance due to railway noise and vibration, as well as on wind turbine noise annoyance. Furthermore, some studies have investigated effects on annoyance of interventions to reduce noise, while some have focused on individual differences in noise sensitivity and annoyance. New insights from recent studies on each of these topics are discussed.

INTRODUCTION

The community response to noise refers to the self-reported annoyance in a “community” or group of residents as assessed by one or more annoyance questions in a survey. Annoyance may result from noise-induced repeated disturbance of activities and may be accompanied by negative feelings such as anger or displeasure and by perceived lack of control. This paper aims to review the recent progress within the field of noise annoyance, based on peer-reviewed publications in the past three years (2014 to 2017) after the previous ICBEN congress and review [1]. Many new studies have been published in this period, among which some general topics may be identified. Developments include an increased focus on local or case-specific as opposed to generalized exposure-response relationships to predict noise annoyance, as well as a renewed interest in the influence of temporal and spectral characteristics on the annoyance at a given noise level. In addition, new research has been published on annoyance due to railway noise and vibration, as well as on wind turbine noise annoyance. Furthermore, some studies have investigated effects on annoyance of interventions to reduce noise, while some have focused on individual differences in noise sensitivity and annoyance. New insights from recent studies on each of these topics will be discussed below.

RECENT STUDIES PER TOPIC

Local or case-specific exposure-response relationships

Generalized exposure-response relationships, based on the average annoyance response as reported by a large number of subjects in a large number of studies, often do not accurately predict the annoyance in a specific case or study. The annoyance response may vary between studies depending on demographic, cultural and situational factors. Furthermore, notwithstanding the publication of standardized annoyance questions by the ICBEN community response team [2], a recent survey study demonstrates that questionnaire-design related differences (e.g. order of the questions, choice of specific question, season in which survey was done) may play a role in the variance between studies in annoyance response [3]. In addition, the annoyance response may depend on whether the noise situation is more or less steady state or whether there has been a step change in noise levels. A recent analysis of many aircraft noise studies over the years [4] showed that the previously observed increase in annoyance response at a given aircraft noise level may at least in part be ascribed to the larger proportion of high-rate change airports in recent times. Lower tolerance for noise was observed in communities around high-rate-of-change airports, with large changes in operational patterns and/or extensive public discussions, than in communities around low-rate-of-change airports. When differences in change status of airports were controlled for, a temporal trend in annoyance was no longer observed.

In one study, a method to determine the community tolerance level (CTL), which has been developed to reflect the community-specific part of the annoyance response at a given noise level, was adapted to reduce uncertainty [5]. Furthermore, when applying the CTL method for assessing the annoyance response to aircraft and road traffic noise in five different cities in Vietnam [6], it was found that the annoyance due to aircraft noise was roughly as expected, but that respondents were much more tolerant to road traffic noise than expected based on generalized exposure-response relationships. Also, a large study in Hong Kong showed lower road traffic noise annoyance than expected based on existing exposure-response relationships, suggesting that cultural differences may play a role [7].

However, deviations from generalized exposure-response relationships are not only observed in non-western countries. In a study comprising 8 cities in France [8], exposure-response relationships for transportation noise recommended by the EU were found to reasonably predict the number of highly annoyed residents due to road traffic noise, but they underestimated annoyance due to railway and aircraft noise. Local exposure-response relationships better described the annoyance in the French cities, and led to a better prediction of total annoyance by combined exposure to the three noise sources. In a case study in the Netherlands with combined exposure to railway and road traffic noise [9], the annoyance response to road traffic noise and in particular railway noise was found to be much higher than expected with generalized exposure-response relationships. By using an optimized noise model based on measured local noise levels and exposure-response relationships based on local noise annoyance surveys, a more detailed impact assessment could be done, including future scenarios.

Sometimes specific situational characteristics may lead to high annoyance. A case study in New Delhi in India [10] showed high traffic volume and high average L_{Aeq} residence levels during the day and night of 68 dB(A) and 64 dB(A) respectively, which all 62 residents in the sample rated as intolerable to extremely intolerable. Another case study in Latin America [11] showed very high equivalent noise levels generated during the passage of a train with its horn blowing, leading to an L_{Aeq} of 80-92 dB(A) at the closest facades. A large majority of residents reported that they were bothered or irritated by the train noise. A study in urban streets in Italy [12] suggests that site characteristics such as street configuration may play a role: at the same

L_{Aeq} level, the annoyance response to traffic noise at sites with broad streets was higher than that at sites with narrow streets. It is not clear whether this was due to differences in attitudes or differences in acoustic characteristics [13].

Influence of temporal and spectral characteristics

Several recent studies have investigated the influence of acoustic characteristics of the noise on the annoyance response at a given noise exposure level. Some of these focus on short-term annoyance by individual noise events, or on the influence of the temporal distribution of events. Also, some are looking for spectral or modulation indices that may influence annoyance in addition to total energy-based indices of noise.

For instance, reported annoyance during a listening test with recorded urban main road traffic sounds [14] was less affected by altering the frequency spectrum in the low frequency range than by equivalent changes in other frequencies, suggesting that the low frequency component was subjectively less dominant.

A study in which subjects evaluated urban road single-vehicle pass-by noises [15] shows that road traffic noise annoyance responses are not only influenced by energy-related noise exposure levels, but also by sound characteristics of environmental noises. Annoyance was influenced in particular by the degree to which noises could be characterized as dull/shrill or sputtering and nasal, which could be partly linked to spectral and temporal signal features. A follow-up study [16] found that, in addition to the noise level, annoyance was influenced by type of vehicle (spectral) and driving conditions (temporal). Also, combined noise situations were investigated, consisting of urban road vehicle pass-by noises heard in the presence of a steady industrial noise. It was concluded that perceptual total annoyance models, taking into account the specific annoyance by both sources, are better suited to assess the total annoyance than a psychophysical model or a strongest component model. Another laboratory study [17] with subjects rating tramway pass-by noises was carried out to identify and characterize the influential acoustical factors related to tramway noise. It was found that both the irregular/continuous character and the bass/treble character of tramway noises influence short-time annoyance, leading to the proposal of additional acoustic indices to take these characteristics into account.

In the COSMA study [18], aircraft noise-induced short-term annoyance was investigated in local residents near a busy airport. It was concluded that noise metrics that directly reflect the number of fly-overs, as well as noise metrics that take into account the outdoor-to-indoor attenuation, can improve the prediction of short-term annoyance compared to models using equivalent outdoor levels only. Furthermore, non-acoustical factors were shown to influence both long-term annoyance and short-term annoyance. Also as part of the COSMA study [19], the impact of changes in airport noise exposure was assessed in a laboratory setting which simulated airport noise scenarios in homelike environments. While results were inconclusive with regard to the aircraft sound quality, it was found that reported annoyance significantly decreased when reducing the number of aircraft. This again suggests that the prediction of annoyance could be improved by taking into account the number of fly-overs in addition to equivalent noise levels. In another attempt to explain the large variability in annoyance (and possibly other health effects) observed at a given exposure level, a metric termed intermittency ratio (IR) was introduced [20], which takes into account the short-term temporal variations of the noise. This metric expresses the proportion of the acoustical energy contribution in the total energetic dose that is created by individual noise events above a certain threshold.

Railway annoyance (noise and vibration)

High-speed trains have become more popular and new high-speed railway lines are currently under construction worldwide. As the speed of the train increases, the disturbance caused by noise in the surrounding areas becomes worse. Therefore, several studies have been undertaken on the community response to high-speed train noise. It is particularly meaningful to study the change in people's reaction to noise caused by the transition from conventional to new high-speed railway, the so-called step-change scenario. In Japan, the annoyance response to railway noise before and after the opening of the new Shinkansen railway line adjacent to an existing conventional railway line was assessed and the difference in responses was evaluated [21]. Contrary to the expected response prior to the opening of the new Shinkansen line, the respondents were more annoyed at a given noise level by conventional railway than by the new Shinkansen railway. While the new Shinkansen line led to a slight increase in noise and vibration exposure, the annoyance response may have been reduced by residents' expectation that their lives would be affected more seriously. The study concluded that no significant increase in the overall annoyance response may be found when the noise and vibration exposure by the new railway lines is less than that of the existing system.

As trains usually reach their maximum speed in rural areas, the disturbance experienced by the residents of such areas can be considered comparatively large. Therefore, there is a need for research on the perception of high-speed train noise in rural areas. In one study, rural areas with high-speed train noise were investigated as a concept of soundscape [22]. On combining a laboratory experiment with panoramic pictures and acoustic stimuli obtained from field measurements, the effect of visual images of rural areas on the perception of high-speed train noise was found to be significant. The higher the percentage of natural features, the less annoyance from a given high-speed train noise.

Many previous studies have provided evidence for the railway bonus, according to which lesser annoyance is caused by railway noise as compared to road traffic noise in the regulations. However, some studies conducted in Japan and Korea reported opposite results. The difference between the findings from these studies could be attributed to noise from other sources or vibrations as well as non-acoustical factors. A study in Pisa, Italy, investigated the effect of unconventional noise sources and vibration on the perception of noise [23]. Unconventional noise sources were characterized as noise sources related to railway operations like maneuvering, loading and unloading, truck movement, braking, squeals, and whistles. Noise perception of the measured noise resulting from unconventional noise sources showed an average increase of 3 points of %HA compared to that of simulated noise without unconventional noise sources. This study supported the reasonable doubt that railway noise impact is generally underestimated. It showed that unconventional noise sources and vibration should be considered in order to prevent people's disturbance from being underestimated.

Many studies that investigated the impact of non-acoustical factors affecting railway noise annoyance used correlation or multiple regression analysis. These analyses are limited in that they provide only simple associations or information only on the direct effects. In one study, structural equation modelling (SEM) that allows testing of a variety of hypotheses was applied to reveal the interrelations between non-acoustical factors and annoyance based on a theoretical model of railway noise annoyance [24]. By considering acoustical and non-acoustical factors in the SEM model, 72% of the variance in noise annoyance could be explained. With regard to the harmful effects of noise and source, coping and noise sensitivity had the highest total effect on annoyance, and it was revealed the noise exposure had a lower effect on annoyance.

Exposure-response relationships have been derived for railway noise from many field and laboratory studies. Compared to this, there is relatively few data for railway vibration. Based on a field study into human response to vibration carried out by the University of Salford, UK [25], exposure-response relationships were derived. Application of frequency weightings was found to improve the correlation between vibration exposure and annoyance marginally. In addition, effects of non-acoustic factors, featuring several situational, attitudinal, and demographic factors, on railway vibration annoyance were investigated with ordinal logit regression analysis [26]. The impact of attitudinal factors, such as concerns about property damage and expectations about future levels of vibration, on vibration annoyance was found to be large in this study. Also, the influence of the presence of audible vibration-induced rattle on annoyance by railway vibration was investigated with these data [27]. Confirming the findings of several previous studies on annoyance response caused by rattle and vibration of aircraft, higher annoyance ratings were found when vibration-induced rattle is audible. It was suggested that quantification of vibration-induced rattle and its effects on humans should be taken into account in future studies. Furthermore, the difference in human response to freight and passenger railway vibration was determined and the exposure-response relationships for freight and passenger railway vibration were derived using an ordinal probit model with fixed threshold [28]. Freight railway vibration caused more annoying response than passenger railway vibration. In terms of the community tolerance level, a metric proposed by Fidell et al., the population studied was found to be 15 dB more tolerant to passenger railway vibration than to freight railway vibration.

The European Union-funded project CargoVibes [29], which aimed to develop and validate measures to ensure acceptable levels of vibration for residents in the vicinity of freight railway lines, involved 10 partners from 8 nations and ran from 2011 to 2014. In a work package on human response, the following aspects were considered: 1) exposure-response relationships and factors influencing these relationships, 2) results of sleep disturbance studies, 3) and a guidance document for the evaluation of railway vibration. Guidance was provided for new policy developments on railway noise and vibration, including exposure-response relationships based on the data from all available field studies [30]. Moreover, it was recommended that in policies concerning railway vibration, attitudinal, situational, and socio-demographic factors be considered when setting vibration limits.

Wind turbine noise

With wind farms being developed in many countries, the community response to wind turbine noise is an important relatively new research field. In a large Canadian study with over 1200 subjects living near wind turbines [31], several personal and situational variables (such as attitudes, visual annoyance, personal benefit) were shown to significantly affect the annoyance response. A Norwegian study [32], in a small sample of 90 residents living near wind turbines, found a higher annoyance response than expected based on earlier international relationships, which was attributed to prevailing negative attitudes and perceived degradation of visual aesthetics as important modifying factors. Also, the familiarity with wind turbine noise may be a modifying factor, since in a listening test with recorded wind turbine noise [33] subjects familiar with the noise were better in detecting wind turbine noise at the lower levels (and also had more false alarms) than subjects unfamiliar with wind turbine noise. Another listening test [34] showed that residents familiar with wind turbines judged wind turbine noise as more annoying than students, with A-weighted sound levels giving a more accurate description of the annoyance than C-weighted noise levels. Furthermore, in the laboratory [35], detectability and perceived loudness of wind turbine noise were enhanced by the degree of amplitude modulation.

Interventions

Some recent studies have investigated the effects of noise interventions (or noise management, or noise control) on community response. Implementing noise insulation programs may be effective in terms of objective and measurable quantities, but the residents' subjective satisfaction cannot always be sufficiently described in terms of objective variables alone. In one study in Spain, the efficacy of the noise insulation programs was determined in terms of the beneficiaries' subjective perception [36]. The beneficiaries were satisfied regarding the insulation of the façade after implementation and they reported a reduction in annoyance. Over 60% of the variability in overall satisfaction could be explained, partly by satisfaction with the insulation itself, but there were also some non-acoustic factors (such as aesthetics and legal aspects) influencing the perception.

Heavy vehicles have noise level emissions that are higher than that of cars, and an increase in the number of heavy vehicles in the road traffic can significantly elevate the noise exposure levels. A study measured the community's response to the intervention of heavy vehicles at night [37]. There were significant reductions in terms of the nighttime annoyance and interference with activities. However, since there was no change in the overall noise exposure level, the reduction in the number of heavy vehicles appeared to have caused the changes in people's response to noise. The need to consider the number of noise events in road traffic as an acoustical indicator affecting community response in the nighttime was suggested.

Various studies have investigated the effect of non-acoustical and environmental factors of noise interventions on noise perception. In one experimental study, visual perceptions of noise barriers including vegetation treatment were investigated [38]. The aesthetic value of the barrier materials contributed to the overall impression of environment, and the vegetation cover of the barrier could reduce noise perception and increase the perceived noise barrier performance. These studies provide useful approaches in formulating optimal strategies for noise barrier design and reducing people's negative perception to noise.

The effectiveness of urban green spaces as a psychological buffer for the negative health impact of noise pollution has not been systematically analyzed before. A systematic review was reported based on MEDLINE and EMBASE databases published before June 04, 2013 [39]. Owing to the limited number of review studies and differences in the methodologies among the studies, researchers could not draw a firm conclusion. However, based on electroencephalogram tests and observational studies, the study suggested that there is moderate evidence that the presence of vegetation can reduce the negative perception of noise.

Another study evaluated the effect of access to a quiet place in one's dwelling on annoyance, sleep, and concentration [40]. Noise exposure levels from road traffic and railway were obtained by calculating the most exposed façade of the buildings from study participants' address. Answers for 2612 questions on the adverse effects of noise exposure were analyzed. Access to a quiet place like a quiet indoor space or a window facing green space was associated with reduced risk of noise annoyance, sleep, and concentration problems.

The relation between noise and well-being has not been well established based on sufficient studies, unlike the case of noise-related annoyance, sleep disturbance, and cardiovascular mortality. In three European cities, noise-related well-being impacts of transport were assessed as part of an EU-project. This study evinced that there exists a relation between noise reduction effects and well-being, with the well-being benefits being mostly realized for population groups exposed to high noise levels [41].

Individual differences

A cross sectional population-based study including 517 primary school children showed that, apart from noise indicators, the family's residential satisfaction and socio-economic factors influenced annoyance by transport noise in the children, with lower residential satisfaction and lower socio-economic level being associated with higher annoyance [42]. In contrast, a study in the Philippines with 321 adults exposed to aircraft noise [43] showed that noise sensitivity, noise exposure level, and affluent status all have positive effects on aircraft noise annoyance, confirming earlier indications that higher affluent people are substantially more annoyed by the aircraft noise than lower affluent people.

In a Canadian community survey assessing road traffic noise annoyance in 610 residents [44], it was found that co-exposure to air pollution, along with odour annoyance and noise sensitivity, was associated with higher noise annoyance. Findings from a study in New Zealand [45] suggest no strong relationship between noise sensitivity and sensitivity to other sensory stimuli, such as odours and air pollution, indicating that negative affect is unlikely to be a general cause of noise sensitivity. A Finnish study with 1112 residents showed that the perception of health risks and positive environmental attitudes were associated with higher road traffic noise annoyance as well as noise sensitivity [46].

CONCLUSIONS

New research papers on the community response to noise published in the previous three years have been presented, showing an increased focus on local or case-specific exposure-response relationships for noise annoyance, as well as on the influence of temporal and spectral characteristics. New research on annoyance due to railway noise suggests that not considering the effects of vibration and unconventional specific railway noise sources may result in underestimation of the annoyance response. Studies on wind turbine noise annoyance showed further evidence for the role of attitudes, visual aesthetics, familiarity with the noise and amplitude modulation. Furthermore, some studies provided evidence on the effectiveness of specific interventions to reduce noise on annoyance, while some have focused on individual differences in noise sensitivity and annoyance.

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