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Effects of different noise combinations on sleep, as assessed by a general questionnaire

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ABSTRACT

In the present study, the effects of different noise combinations on sleep were assessed in two contexts, with a single noise source and with combined noise sources. Road traffic noise, and construction or movie noise combined with road traffic noise were used as the single noise source and the combined noise sources, respectively. When the sound pressure level of road traffic noise was kept constant, levels of the construction and movie noise were changed. Twenty participants were followed for approximately 2 weeks, during which their sleep was evaluated using a questionnaire, including questions on sleeping behavior, premature awakening, and subjective responses. The results showed that the combined noise sources including construction noise decreased the number of participants who fell asleep within an hour and increased the number that were awakened prematurely compared to the effects of road traffic noise combined with movie noise. However, similar tendencies were observed while evaluating sleep quality, sleep disturbance, and annoyance.

1. Introduction

Environmental noise causes a variety of adverse health effects such as annoyance, speech interference, and sleep disturbance [1]. Moreover, nocturnal noise causes premature awakenings, difficulties in falling asleep, as well as a decrease in subjective sleep quality. Noise-induced sleep disturbance has been investigated through field surveys and laboratory experiments [2–5]. A few studies have compared field results with those from a laboratory and have concluded that laboratory experiments did not exaggerate the effects of noise on sleep [6,7].

In order to measure the adverse effects of noise on sleep, a wide range of methods has been used. In several field surveys, premature awakening, referred to as behavioral awakening, was measured [2,3]. Participants were asked to press a button when they were awakened. EEG data from polysomnography and motility (gross body movement) were applied as a more sensitive measure of disturbance than that of simple awakening [8,9]. In addition to objective measurements such as awakening, EEG, and motility, the questionnaire survey has been used for subjective evaluations of sleep [10,11]. Subjective evaluations of sleep were often obtained in conjunction with more detailed sleep measurement methods by having participants complete evening or next-day questionnaires.

Most previous studies on sleep disturbance have focused on transportation noises, especially road traffic and aircraft noise [2–11]. However, recent studies have dealt with various kinds of environmental noises in laboratory experiments because most residents are exposed to conversation, songs, and noise from construction, as well as road, aircraft, and railway noises. Kuwano and Mizunami [12] used a simulated air-conditioner noise, Karaoke song, conversation between two people, as well as road traffic noise. Namba et al. [13] investigated the sleep disturbances caused by meaningful sounds. However, most of these studies dealt only with a single noise source, with the effects of combined noise sources being rarely investigated. Recently, the adverse effects of combined noise sources have been reported in terms of annoyance and speech interference because community noises are concurrent [14–16]. There are also possibilities that residents are exposed to concurrent noise during sleep. Therefore, combined and single noise sources should be considered in sleep disturbance studies.

In the present study, the experiments on noise-induced sleep disturbance were performed in the participants' homes. During the experiments, the participants were exposed to road traffic noise (single noise source) and road traffic in combination with construction or movie noise (combined noise sources). The effect of noise on sleep was evaluated by questionnaire, including questions on sleeping behavior, premature awakening, and subjective responses.

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2. Material and methods

2.1. Stimuli

Road traffic noises, with small variations in noise level, were recorded alongside a road approximately 40 m in width using a binaural microphone (B&K, Type 4101). The average vehicle speed on this road was 60 km/h, and the percentage of heavy vehicles was around 20%. The construction noises were also recorded in a construction field including breakers and excavators, which are widely used for road repair work at night. For simulating noise from neighboring houses, 5-min of sounds were extracted from an action movie.

Broadband attenuation (geometric spreading) and additional attenuation of the high frequency components (air absorption) were applied to the road traffic and construction noises. Further, spectral filtering was also applied to simulate the various frequency-dependent outdoor-to-indoor noise reductions. In a previous study, Vos [17] provided five façade types with different frequency-dependent sound reductions from closed widows (very high isolation) to wide-open windows. In this study, an attenuation of the closed widows with a median degree of isolation was adopted. In this condition, the façade attenuation increased from 12 dB for 16 Hz and 31.5 Hz, up to 35 dB for 8 kHz. The spectral characteristics of movie noise were also modified to simulate propagation through drywall with an airborne sound transmission performance of R_w 55. It was assumed that the drywall consists of two fire resistant gypsum boards with a thickness of 15 mm, absorption material of 50 mm-thick, and an air cavity of 50 mm. The movie noise after spectral attenuation was regarded as unmeaningful sound.

Fig. 1 shows the frequency characteristics of road traffic, construction, and movie noise after applying the spectral attenuation when noise levels were fixed to 45 dBA. The spectral contents of road traffic noise and movie noise were dominated by energy in the low frequency range below 250 Hz, whereas construction noises had less sound pressure levels in the low frequency range than road traffic and movie noises.

Various sound pressure levels of road traffic, construction, and movie noises with a length of 5-min were analyzed in terms of percentile metrics (L_5, L_{10}, L_{50}, and L_{90}), as well as *A*-weighted equivalent sound pressure levels (L_{Aeq}) and *A*-weighted maximum sound pressure levels (L_{Amax}). L_5, L_{10}, L_{50}, and L_{90} describe the level exceeded for 5%, 10%, 50%, and 90% of the measuring period, respectively. Therefore, these are useful measures for investigating the temporal characteristics of sound varying over time. Analysis results for road traffic, construction, and movie noises are listed in Table 1. When the L_{Aeq} of road traffic noise was fixed at 35 dBA, other level indices showed similar results and level difference between L_{Amax} and L_{90} was 2.2 dB. Thus, road traffic can be regarded as stationary sound according to the classification of environmental noises stated in the ISO 1996-1 [18]. In the case of movie and construction noises, the differences between levels were larger than that of road traffic noise. For instance, the L_{Amax} of construction noise was the highest at 42.0 dB, while the L_{90} was the lowest at 28.0 dB. The larger difference between percentile values is due to peaks generated by the breakers.

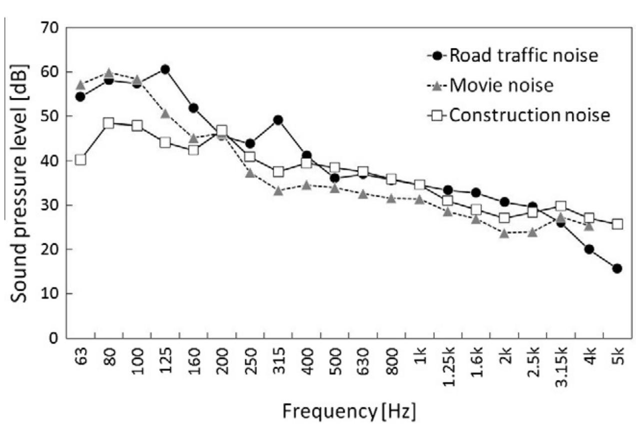

Fig. 1. Frequency characteristics of road traffic, movie, and construction noises.

2.2. Experimental design

As described in Table 2, the experiments were designed to have a total of seven situations for the evaluation of noise effects in two contexts, with a single noise source and with combined noise sources. Road traffic noise was considered as an individual noise source, and construction and movie noise combined with road traffic noise were considered as combined noise sources. The L_{Aeq} of road traffic noise was fixed at 35 dBA, corresponding to the noise exposure of previous studies in the range of 30–35 dBA [7,12,13]. When the sound pressure level of road traffic noise was maintained at 35 dBA in terms of L_{Aeq}, the levels of the construction and movie noises were varied from 30 to 45 dBA in increments of 7.5 dB. Thus, the sound pressure level difference between construction, movie, and road traffic noise had variations of −5, +2.5, +10 dB.

2.3. Experimental procedure

The experiments were performed in the participants' bedrooms during the winter (from December to February). In order to avoid the effect of outside noise on sleep, only participants who lived far away from the motorway were chosen, and the windows were kept closed during the experiments. Thus, background noise levels of the bedrooms were controlled to be less than 25 dBA overnight.

In the experiments, 5-min recordings were repeatedly presented to the participants via sound isolating earphones (Shure, E3c) and an MP3 player (Sony, NW-E005) in a manner similar to those of previous studies [12,13]. The frequency response of the whole listening system was flat within 3 dB (1/3 octave-band levels, 20–16,000 Hz) through calibration using a pink-noise signal. It was unusual for most participants to sleep with earphones. Thus, participants wore the earphones while sleeping for three nights prior to the experiment, with most participants indicating that they were accustomed to sleeping with the earphones within three nights. This result is in good agreement with those of a previous

Table 1
Equivalent and percentile sound pressure levels for road traffic, movie, and construction noises [dBA].

	L_{Aeq}	L_{Amax}	L_5	L_{10}	L_{50}	L_{90}
Road traffic noise	35.0	36.5	36.2	35.9	34.9	34.3
Movie noise	37.5	41.1	40.6	40.3	37.7	32.3
Construction noise	37.5	42.0	41.5	41.2	37.6	28.0

Table 2
Outline of the experiment (T: road traffic, C: construction, and M: movie noise).

	Sound pressure level [dBA]		
	T	C	M
Individual noise	35	–	–
Combined noise sources	35	30, 37.5, and 45	30, 37.5, and 45