ANNOYANCE CAUSED BY MAGNETIC LEVITATION TRAIN TRANSRAPID 08

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ABSTRACT

The annoyance caused by the sounds from magnetic levitation train (Transrapid) passbys was investigated in the laboratory. Four important results were obtained. Provided that the outdoor A-weighted sound exposure levels (ASELs) were the same, 1) the annoyance was independent of the driving speed (100-400 km/h) of the Transrapid, 2) the annoyance caused by the Transrapid was considerably higher than that caused by more conventional (intercity) trains, and 3) the annoyance caused by the Transrapid was hardly different from that caused by road traffic (passenger cars and trucks). These results 4) held true for the two simulated façade attenuation conditions (windows open or windows closed). In conclusion, it might be expected that the sounds are equally annoying if the ASELs of the Transrapid passbys are at least 5 dB lower than those of the intercity train passbys.

INTRODUCTION

In the interest of improving the infrastructure of the Northern part of The Netherlands, an intelligent choice among various alternative measures required detailed knowledge about the annoyance caused by the sounds from magnetic levitation train (Transrapid 08) passbys. Some data on overall loudness (rather than annoyance) of Transrapid 07 and more conventional train passages have been reported by Fastl and Gottschling (1996). Since at present, there are no tracks of the Transrapid located in or close to residential areas, a field survey could not be carried out. Consequently, the research was performed in the laboratory, where listeners had to rate the annoyance of various sound fragments. The independent variables were a) the driving speed of Transrapid 08 (varying from 100 to 400 km/h), b) the outdoor A-weighted sound exposure level (ASEL) of the passbys (varying from 65 to 90 dB), and c) the simulated outdoor-to-indoor reduction in sound level (windows open or windows closed). As references, sounds from road traffic (passenger cars and trucks) and more conventional railway (intercity trains) were included for rating also.

METHODS

Sound Fragments

The sounds of Transrapid 08 were recorded in Lathen, Germany. We selected passages at four driving speeds (100, 200, 325, and 400 km/h), each passage being simultaneously recorded at three distances of 25, 50, and 100 m. From these 12 recordings, 16 different sound fragments were prepared. Each fragment consisted of one passage with a duration of 15-20 s. Since the total duration of all fragments included in the present study was fixed at 45 s, the Transrapid passages were preceded and followed by silent periods of about 12-15 s. The passages with driving speeds of 100 and 200 km/h were presented at outdoor ASELs of 65-80 dB. For the speeds of 325 and 400 km/h, the ASELs ranged from 75 to 90 dB.

The fragments of the intercity trains were based on the sounds from passenger trains (types ICR/ICM and IRM/DD) recorded at distances of 35 and 100 m. The driving speed was equal to 120-140 km/h, the duration of a passage was equal to 25-30 s. The fragments of road traffic were based on the sounds from passenger cars and trucks recorded at distances of 12.5-60 m from a provincial road. The driving speed was equal to about 80 km/h. Each fragment consisted of partly overlapping passages of 10-12 different passenger cars and one truck, with a total duration of 45 s. The maximum A-weighted levels of the truck passbys were about 10 dB higher than those of the passenger car passbys (Versfeld and Vos, 1997, 2002).

For the conditions in which it was simulated that the windows were wide open, a fixed façade attenuation of 5 dB was assumed for frequencies between 12.5 and 1000 Hz. For higher frequencies the attenuation was 8 dB at most. With the windows closed, the façade attenuation increased from 12 dB for the 16-Hz and 31.5-Hz octave bands up to 35 dB for the 8-kHz octave band, and represented the average of noise attenuations that are frequently found for Dutch dwellings with the windows closed (Vos, 2001).

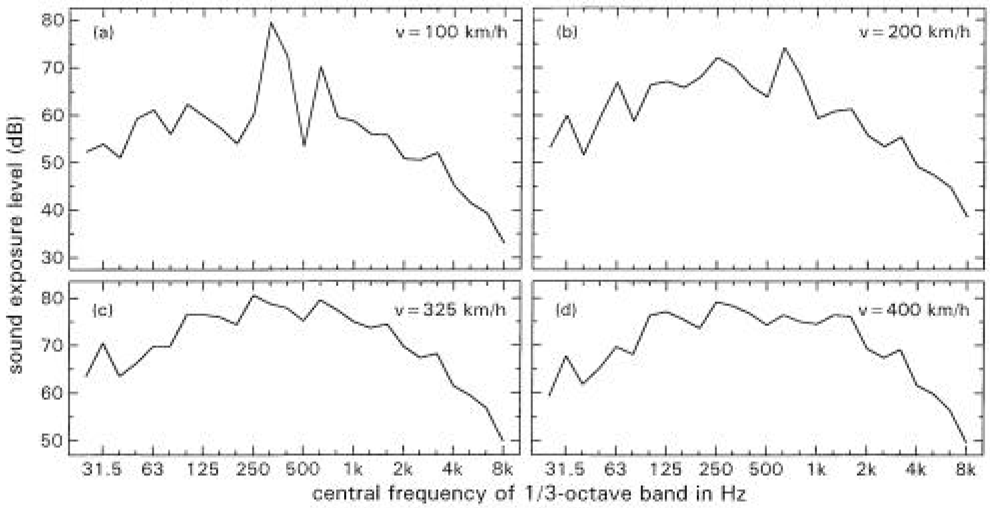


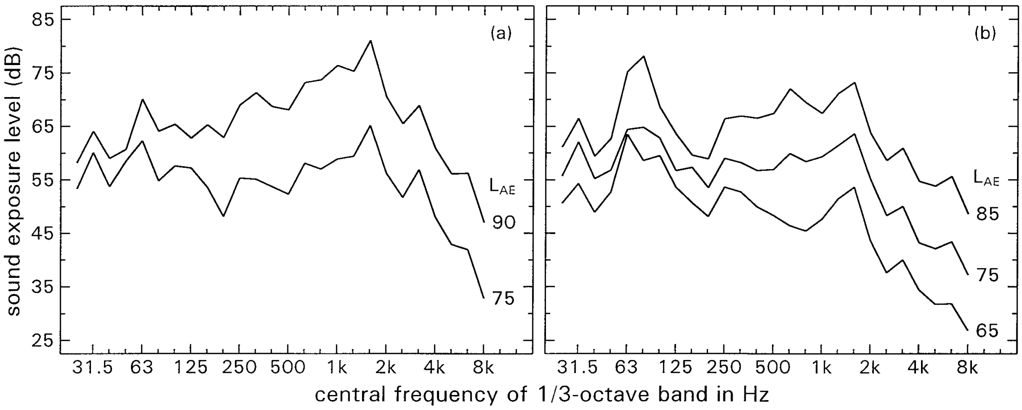
Fig. 1. Spectra determined for four speeds of the Transrapid passbys.

Figure 1 shows the linear sound exposure level (SEL) in the various 1/3-octave bands for a few passages of Transrapid 08. The spectra were determined in the windows-open condition at the position of the heads of the listeners. For each driving speed only the spectrum in the condition with the highest ASEL (and smallest recording distance) is shown. For the lower ASELs (greater recording distances), the relative differences among the spectra were small. Figure 1a shows two characteristic spectral peaks around 315 and 630 Hz for the driving speed of 100 km/h. For a speed of 200 km/h, the peak around 315 Hz is strongly reduced. For the speeds of 325 and 400 km/h, relevant spectral energy is found for a wide range between 100 and 2000 Hz.

Figure 2a shows two of the four sound spectra for the intercity trains. In addition to the smaller spectral peak around 31.5 and 63 Hz, a highly significant peak around 1600 Hz is obtained. Figure 2b shows three of the five spectra for the fragments with road-traffic sounds.

A Few Other Aspects

Twelve normally hearing subjects between 23 and 34 year of age participated in the experiment. The subjects were told that they were exposed to conditions in which traffic sounds could be heard either for the entire time period of 45 s, or for a portion of this time period. The beginning and end of each 45 s condition was indicated on the monitor of their personal computer. The task of the listeners was to respond after each condition to the question “How annoying would you find the sound in the preceding period if you were exposed to it at home on a regular basis?” They were encouraged to use the whole range of the rating scale with values from 0 (“not annoying at all”) to 9 (“extremely annoying”). Six subjects started with the windows open conditions, and the other six started with the windows closed



conditions. Each condition was presented twice for rating. Both for the first and for the second ratings, presentation order of the conditions within each façade attenuation type was randomized.

Fig. 2. Spectra determined for sound fragments with a) intercity trains, b) road traffic.

RESULTS

In line with noise zoning procedures, the annoyance will be related to outdoor levels. From the correlation coefficients, *r*, computed between the first and second ratings for each subject separately, it was concluded that for both façade conditions, the reliability of the annoyance scores was satisfactory (*r* ranged between 0.54 and 0.88, M = 0.73, sd. ~0.09). Moreover, the mean scores obtained in the first measurements were not significantly different from those obtained in the second measurements, and in general, there were no significant interaction effects between replication and the stimulus variables.

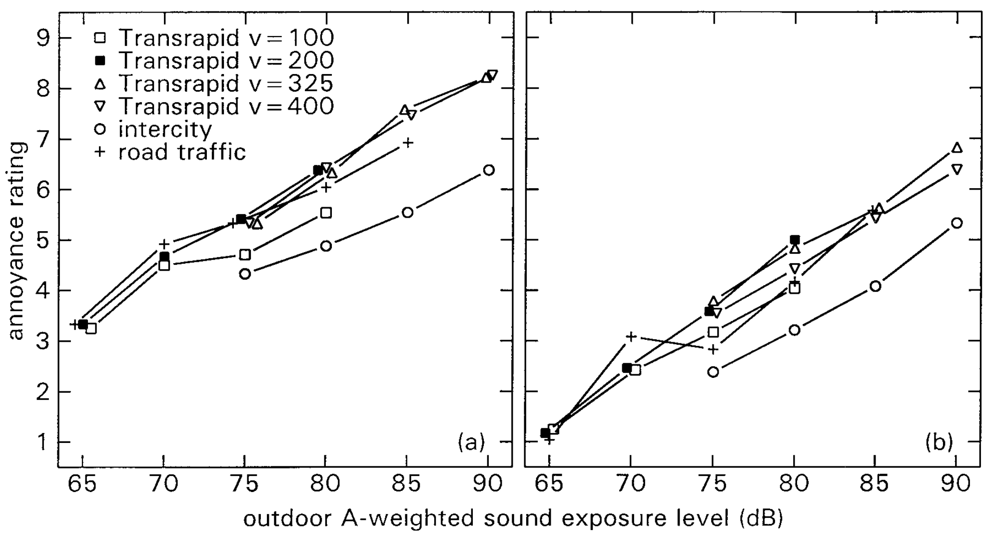


Fig. 3. Mean indoor annoyance ratings for the various sound fragments, as a function of outdoor levels. a) windows open, b) windows closed.

Windows Open

For the conditions in which it was simulated that the windows were wide open, Figure 3a shows the annoyance scores, averaged across subjects and replications, as a function of outdoor ASEL for each sound source separately. Three overall effects were obtained. Firstly, the annoyance significantly increased with ASEL. Secondly, provided that the ASELs were the same, the annoyance caused by the Transrapid sounds was not significantly different from the road-traffic sounds. Actually, there was one minor exception: For ASELs between 65 and 80 dB, the annoyance caused by the Transrapid passing by at a speed of 100 km/h was slightly lower than the annoyance caused by road traffic and the Transrapid passing by at a speed of 200 km/h. Thirdly, again for equal ASELs, the annoyance caused by the intercity trains was significantly lower than that caused by Transrapid and road traffic.

By and large, three main conclusions may be drawn. At comparable ASELs a) the annoyance was practically independent of the driving speed of the Transrapid, b) the annoyance caused by the Transrapid was not different from the annoyance caused by road traffic, but c) considerably higher than the annoyance caused by the intercity trains.

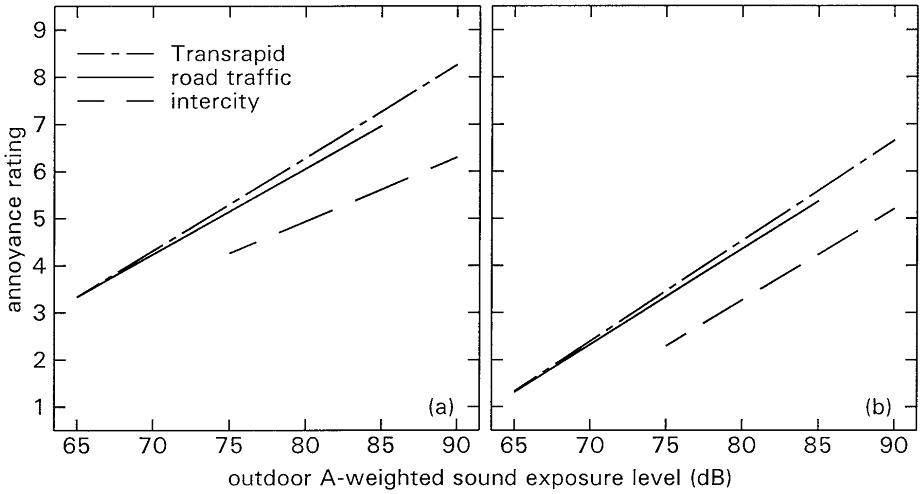


Fig. 4. Dose-response relations for three sound sources. a) windows open, b) windows closed

Figure 4a shows the three dose-response relations. The relations were obtained by linear fits of the 16 mean ratings for the Transrapid (*r* = 0.98), the five mean ratings for road traffic (*r* = 0.98), and the four mean ratings for the intercity trains (= 0.995). With road traffic as the reference, Figure 4a demonstrates that the bonus for the intercity trains varies from about 5 dB at L_{AE} = 75 dB to about 9 dB at L_{AE} = 90 dB. The difference in annoyance between the train types can be quantified as well: The types are equally annoying if, dependent on sound level, the ASEL of the Transrapid passby sound is 5-10 dB lower than that of the intercity train passby sound.

Windows Closed

Figure 3b shows the mean annoyance scores for the conditions in which it was simulated that the windows were closed. Basically, the results correspond to those obtained in the windows-open conditions. The driving speed of the Transrapid did not significantly affect the annoyance and overall, the annoyance caused by the Transrapid sounds was not significantly different from the annoyance caused by the road-traffic sounds. The unexpectedly high annoyance caused by the road-traffic sounds at L_{AE} = 70 dB is related to the casual presence of relatively much low-frequency energy in the truck passby sound.

Figure 4b shows the dose-response relation for the Transrapid (*r* = 0.99), road-traffic (*r* = 0.96) and intercity train sounds (*r* = 0.995). With road traffic as the reference, a 5-dB bonus for the intercity trains is obtained. In contrast to that found in the windows-open condition, the bonus in the windows-closed condition was invariant with ASEL. The train sounds are equally annoying if the ASEL of the Transrapid passby sound is 6 dB lower than that of the intercity train sound.

RAILWAY BONUS

Both in the windows-open and in the windows-closed conditions, the annoyance caused by the intercity trains was considerably lower than that caused by road traffic, provided that the ASELs were the same. Averaged across the two façade attenuation types, the bonus for the intercity trains was equal to about 6 dB. Support for a railway bonus has been found in field surveys conducted more than 20 years ago (e.g., see Heimerl and Holzmann, 1979; Schümer-Kohrs et al., 1981; Knall and Schümer, 1983; Fields and Walker, 1982). On the basis of the results of a recent meta-analysis it might be concluded that for A-weighted day-night levels of 55-60 dB the railway bonus is equal to about 5 dB, and for the day-night level of 70 dB, the bonus is equal to about 10 dB (Miedema and Vos, 1998). The bonus for the intercity trains obtained in the present experiment corresponds well with the mean bonus found in field surveys for residential areas with moderately high exposure levels. It should be emphasized that in contrast with the preliminary loudness data reported in Fastl and Gottschling (1996), the results of the present experiment do not support application of such a bonus to the Transrapid sounds.

CONCLUSIONS

At equal outdoor ASELs: 1) the annoyance was virtually independent of the speed of the Transrapid passages, 2) the annoyance caused by the Transrapid passby sounds was hardly different from the annoyance caused by the road-traffic sounds, and 3) the annoyance caused by the intercity train passages was considerably lower than that caused by the Transrapid and road-traffic sounds. These results 4) held true for the two simulated façade attenuation conditions. Moreover, 5) it was concluded that the sounds might be expected to be equally annoying if the outdoor ASELs of the Transrapid passbys are at least 5 dB lower than those of the intercity train passbys.

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