PERCEIVED NOISE ANNOYANCE CAUSED BY MAGLEV TRAINS

SCIENTIFIC REPORT

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A study proposed by:

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Directorate-General of Passenger Transport
Projectorganization Zuiderzeelijn
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1. Introduction and objectives

The introduction of new, magnetic levitation railway systems has raised some concern about the noise annoyance. In several countries train noise has less restrictive noise regulations – expressed in time averaged sound level, L_{Aeq} – than noise from other sources such as highways, mayor roads or aircraft because of this observed difference in effect. Current concern mainly involves the effect of magnetic levitation and other high speed railway systems on perception of train noise both through spectral changes (due to a higher fraction of aerodynamic noise) and reduced rise time.

Also prior to this study, noise annoyance caused by high speed trains, both conventional and magnetic levitation (for which no field experiments are possible), has been investigated. The results obtained were not conclusive. Previous work has neglected a few potentially effective factors that were judged to be of importance by additional experts consulted and by the steering committee of a previous project comissioned by the Ministry of Transport, Public Works and Water Management. When short fragments of sound are used to study annoyance differences between trains and between train and road noise, the temporal effect partly gets obscured. Longer exposure, containing several train passages and the typical quiet periods in between, seems necessary to study. Obviously, one can ask participants in the experiment to imagine a situation where the sound is present for a longer period of time ("assume you heard this noise regularly at home …") but it is far from certain that this indeed leads to the expected result. Secondly, the representativity of most previous work has been questionned, as mostly only a very small group of test persons is used. A third point of concern had to do with the participants themselves in the experiment. It is well known from environmental noise questionnaire surveys that personal factors such as noise sensitivity influence noise annoyance. If the participants all belong to a particular subgroup of the population, the result may get coloured and become less representative.

The current experiment tried to solve the above mentioned questions by its design. A few novel methodologies had to be introduced to do this. The global objective was to provide valid research results that can be utilized for setting a standard for reducing noise annoyance of a high speed magnetic levitation train (maglev), in particular in comparison to intercity trains, conventional high-speed trains and road traffic (free flow highway traffic sound). In addition, it was the goal of this project to determine the degree of perceived noise annoyance as a function of acoustic characterizations due to number of passages (and silent inter-passage periods), speeds of train passages and propagation distances to track/road. A home situation was to be created, in which the test persons are exposed to longer fragments of sound, together with quiet periods. The assessment of the influence of non-acoustical factors, such as perceived distance to the source, on annoyance was also an objective. Finally, part of the goal of this project was to perform the experiment with a set of panellists which is representative for the Dutch population at least in factors that are generally believed to be important modifiers for perception of noise annoyance.

This research was guided by a steering committee consisting of Gilles Janssen (dB Vision), Annemarie Ruysbroek (RIVM) and Martin Vandenberg (VROM).

2. Overview of the project components

The field experiment conducted, aimed at creating a natural setting with ecologically valid reproduction of the sound field under study (Figure 1). The use of panellists that were typical for the Dutch population allowed to control for non-acoustical factors.

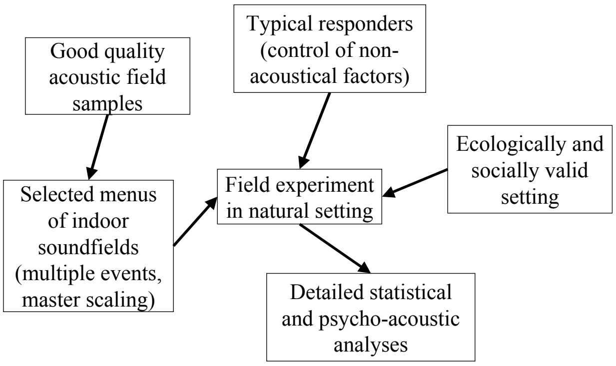


Figure 1. General layout of the project

The selection of typical responders (panelists)

The vision was to create a test panel which is well defined and “representative” of the population of the Netherlands. Because of this representativeness, non-acoustical factors that may influence the perception of noise annoyance would not influence results too much. An innovative selection procedure with inclusion and exclusion criteria of noise-annoyance questionnaire respondents was utilized for this purpose. A two-step procedure is used:

Step A. Volunteers are recruited from the population within a given distance from the measurement location. A brief postal questionnaire is distributed to this sample containing questions on noise annoyance and personal characteristics relevant to noise annoyance (renter/owner of home, age, children/no children; attitude towards new technology; potential benefitters/victims; noise annoyance, environmental worry, noise sensitivity, perceived health, hearing abilities, etc.). The last recruiting question asks for participation in a subsequent follow-up experiment. Monetary encouragement (100 euro) is offered.

Step B. Typical questionnaire responders are selected as potential panelists in the experiment based on the resemblance of their response to the questionnaire to the response of a typical inhabitant of the Netherlands. Depending on the question, a recent RIVM noise annoyance study or the Eurobarometer response for the Netherlands are used as a reference. In this way representativity for the Dutch population is obtained. As the number of participants is limited by the setup of the experiment and the available time frame, to 80+21 participants, representativity can only be obtained for a limited number of non-acoustical factors. Known and expected modifiers are therefore focused in the selection process.

More details on the selection of panelists and an analysis of their representativity can be found in Section 3

The test location, an ecologically and socially valid setting

As a test location we decided for the living room of a house in rural area. This choice resulted in a visual and auditive environment that is a more natural environment for relaxing than for example an anechoic room. In contrast to most experiments of this type, the sound field was stereophonically reproduced outside, resulting in a very natural indoor sound environment. The acoustic insulation of the house (window slightly open) is a natural one, which eliminates problems one may face when producing the indoor soundscape artificially based on outdoor recordings. No visual presentation of the passing trains was given since it seems unnatural that one would see the train passage from indoor especially in an environment with plenty of trees. Anyhow, it would be extremely hard to produce visual reality in this setting. Thus, panelists have only auditory clues.

Details on the house and some pre-tests of the recording and playback methodology are given in Section 5.

Good quality acoustic field samples

At the start of the project, the optimal measurement method for reproducing the sound field of a train passage was obtained by comparing real and recorded passages inside a house located near a railway. The measurement procedure decided upon, is based on two microphone recording. Hence the existing monaural recordings of the Maglev sound could not be used, but fortunately it was possible to travel to Lathen (Germany) and collect appropriate recordings. At that time, the driving conditions could not be controlled so the measurement crew had to wait for suitable passages. The originally planned train speeds of 300 and 400 km/h were approximately reached. A Maglev passage at a speed of 100 km/h that was also foreseen in the original offer could not be recorded. Eventually it was decided to change the experiment and include a recording of a passage at 200 km/h instead of the originally planned 100 km/h sample. This choice was supported by two observations. Firstly, the pass by level of a Maglev train at 200 km/h is already quite low so it could be expected that even lower levels would almost be not audible for the panelists. Secondly, as can be seen from Figure 2, the level (and source type) seems to be quite constant below 200 km/h.

Reference sound fragments for a TGV at 300 km/h were recorded in the south of Belgium while TGV's at lower speed and IC trains were recorded near the Belgian/Dutch border. The original road traffic noise that was used as a reference was recorded near the E40 highway between Gent and Brussels, which is a 6 lane highway furnished with DAC surface.

As lower intensity roads are of scientific interest to the researchers involved, we eventually tested 6 more fragments of road traffic sound in a set of experiments that followed the actual project. These fragments were recorded on local roads at different distances and different traffic intensities (time-of-day). We call this experiment, the **extra experiment** henceforth.

More details on the measurement setup and the samples used can be found in Section 4.

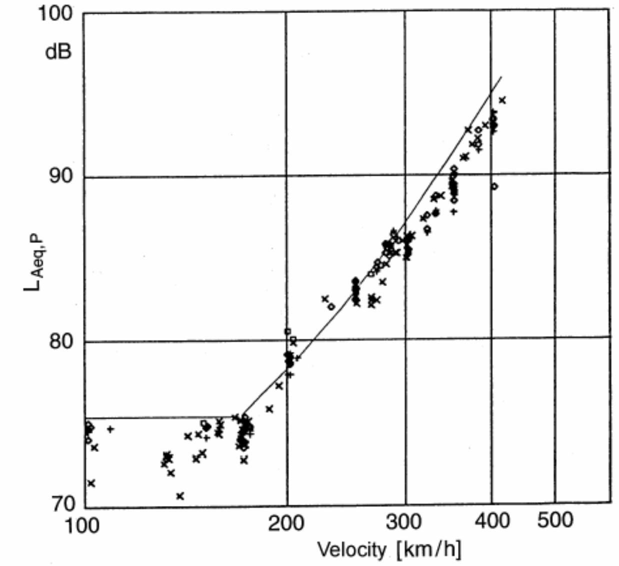


Figure 2 Average pass-by level of TR 07 on elevated concrete track, measured at 25 m distance and predicted (source: Acoustical research on maglev train for the Zuiderzeelijn, Report No. 50694/2, by M+P and Muller BBM, november 2001)

The field experiment in natural setting.

The psychoacoustic experiment that was conducted fulfils the requirements of a controlled laboratory experiment. Still, it includes elements of a natural setting as regards indoor soundscape in an ordinary room, ordinary home activity (relaxing, reading newspaper), and long-term exposures of train and road noise embedded in natural (background) indoor soundscapes. Compared to earlier research, main important features were the multiple-event evaluations in one part of the experiment (ca 2-h session) and the one-event evaluations in a second part of the experiment (ca. 1-h session). The first part – henceforth called **experiment 1** – is the part of the experiment that fulfills the requirements imposed by the objectives of this project. The latter part – henceforth called **experiment 2** – is mainly included to allow to compare our experiment to earlier investigations. In experiment 1, train passage menus of 10 minutes were presented to the panelist. Each of these menus contained a one of the experimental sounds. The experimental sounds for trains were constructed by repeating the same passage two or four times. The road traffic menus contained a single 10 minute recording. To limit the duration of the experiment, not all subjects could be exposed to the all menus. The careful grouping of menus in experimental sessions is detailed in Section 6.

The vision behind the proposed experimental design is to make allowance for comparability between perceived noise annoyance scaled within and between "menus" of transport noise (sets of train passages or road traffic noise) and within and between participants. The principle of master scaling is applied by which perceived noise annoyance of different participants may be "calibrated" to a common master scale.

The 80 panelists that were selected for the main experiment and the 21 additional panelists that were selected for the extra experiment participated in subgroups of 4-5 panelists in the experiment.

Each component of the project is discussed in detail in the following sections.

3. Selection of panelists

The selection process of subjects into experimental studies is often neglected. It is believed the more superior control about the experiment guarantees already generalization across situations, groups and contexts at large. This (hidden) belief is the main reason why in these experiments typically convenience sampling is the technique of choice, which leads to small samples of students, lab or administrative personel in these studies.

However, in situations, where an experiment is crucial for a regulation process it should be noted that the requirements differ. Here, the first goal is the general protection of human beings against the introduction of new/alternative societal activities or the limitations of activities which could potentially harm health or impair life quality. A second goal is also to decide on various alternative measures which could be chosen by the society to reach the same goal without compromising health or quality of life.

Keeping these regulatory demands in mind the requirements for experiments must change to some extent to serve the specific needs.

We tried to accommodate the design of this experiment for this specific goal by adjusting the balance between external and internal validity.

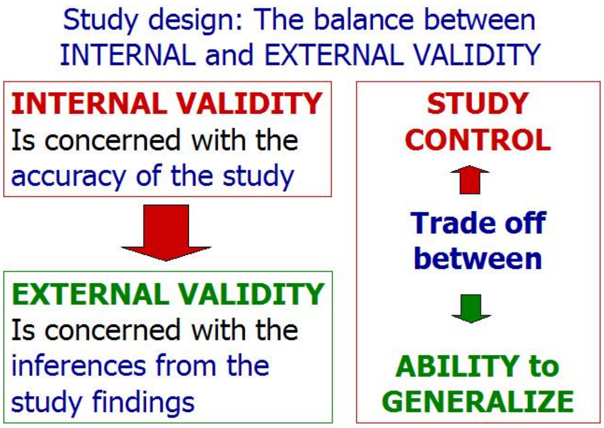


Figure 3. The balance between internal and external validity in designing a study

Among the various requirements one could make a list of those which have higher importance. We tried to adapt this experiment to what we believe are the three most important issues.

By doing this

1. The experiment should represent the real population: representativeness
2. The experiment should represent real life conditions: ecologic validity of the test conditions
3. The experiment should represent real sound conditions: ecologic validity of the test exposure

The first requirement is to be fulfilled by an appropriate selection process of the panelists from the existing population. The selection process should be guided by information you gather on the potential pool of panelists before the experiment starts. The information is typically collected through postal questionnaires.

We were aware, that the expected response to questionnaires in the Netherlands is in the lower part of European countries.

This could be drawn from the Eurobarometer participation rates (see Table 1), and other recent experiences from the HYENA study (personal communication from D Houthuijs), where even lower rates were achieved.

EB58.2: THE MENTAL HEALTH STATUS OF THE EUROPEAN POPULATION

Country	Response rate
France	84
West Germany	78
East Germany	77
Spain	73
Austria	68
Portugal	66
Italy	60
Luxembourg	59
Sweden	51
Belgium	49
Netherlands	47
Finland	44
North Ireland	43
Greece	41
Ireland	33
Denmark	32
Great Britain	23

Table 1. Example of response rates that could be expected

Because the experimental design was much more demanding for the selected, potential respondent than answering a questionnaire, an even lower response rate had to be expected. Therefore, it was planned from the beginning to booster participation by a reasonable amount of money (100 €) for compensation of the efforts, time losses and travel expenses of the participants of the experiment.

In Section 3.1, a short description of the instruments is given, which were used to support the selection process. The selection process itself to guarantee the intended representativeness is explained in Section 3.2. In Section 3.3, we analyse the result of the selection procedure by comparing the distribution of critical characteristics of the test panel to the distribution of these characteristics in the survey that was used as a reference.

3.1. The questionnaire used for participant selection

All three partners have previous experience with setting up annoyance questionnaires and there was agreement to use as far as possible well established questionnaire items from standardized surveys, There was an early input from the steering committee to use questions from the most recent Dutch monitoring survey on noise annoyance. There was also an early intention of the investigators to use Eurobarometer questions to have comparable data for the Dutch population on other than annoyance items. The most difficult task was to limit the number of questions.

The process of reduction was painstaking and based on weighting both major review articles about modifying factors of the annoyance process (Job 1988, Job 1991, Fields 1993, Lercher 1996, Guski 1999, Miedema & Vos 1999, Miedema & Vos 2003) and personal experience from experimental (Berglund) and field studies (Botteldooren, Lercher).

The final version was defended after an extensive exchange with the appointed experts of the steering committee (from RIVM). Based on this interaction process, we eventually omitted one Eurobarometer question (question B4 on environmental opinions) which was considered too sensitive by the RIVM experts in terms of the current environmental policy climate.

The final questionnaire was divided into two parts: part 1 consisted of 16 questions (partly abridged) from the Dutch annoyance survey and 16 questions from other standard questionnaires (see Appendix A for a short list of the items and Appendix B for the full questionnaire).The questions chosen from the Dutch annoyance survey were standard questions regarding perception, annoyance and sleep disturbance from noises in the neigbourhood. Included were a rating of the quality of the neigbourhood in terms of housing and other environmental pollution and overall satisfaction with the current living situation. Further questions concerned basic demographic variables such as age, gender, education, housing, family size and work arrangements. These demographic questions are needed for both the selection procedure and for potential adjustment if confounding would be an issue to be controlled in the analysis process. Moreover, these variables could be essential factors themselves if you would like to stratify on dose-response curves or tests on interactions with other factors.

Part 2 consisted of questions with regard to general and mental health, hearing ability, environmental background/opinion/worry, and environmental sensitivity. For these questions there is less consensus in the noise annoyance community and therefore it was more difficult to find agreement on these questions.

Environmental background/opinion/worry: Out of the long list of modifying factors, mentioned in several reviews (Job 1988, Job 1991, Fields 1993, Lercher 1996, Staples 1996, Steinheider & Hodapp 1998/1999, Guski 1999, Miedema & Vos 1999, Lercher & Schulte-Fortkamp 2003) attitudes toward the environment, experiences with the environment and environmental and health worries are consistently associated with stronger annoyance ratings. It was considered to be important to have a balanced mix of persons with regard to this attitudinal background in a experiment with - epidemiologically speaking - small numbers of participants. Questions B1, B2, B3_1, B3_2 were finally chosen (see Appendix A, part 2) B4 was omitted based on RIVM expert advice.

General health: It is a common hypothesis that persons in bad health conditions may be more easily disturbed by disruptions of their everyday life activities through environmental noise exposure. This is the reason, why in land use planning, hospital areas and other areas with sick persons (nursing homes) get a higher protection from noise exposure. In the literature, specific support for this notion is limited and confined to persons with depression and anxiety (Stansfeld et al 1996; Stansfeld et al 2000; Stansfeld & Matheson 2003). This was the reason why we also included the 3 mental health questions (B7_1 to B7_3) and the general anxiety rating (A3_2) from Franssen et al (2004).

Because most of the available standard questionnaires (GHQ, SF36 etc) on general and mental health (GHQ, SF36 etc) were too long or the shorter versions not specific enough for the purpose of this study, the investigators resorted to selected standardized questions from surveys where for most items also Dutch data were available.

This repeated process of item selection resulted eventually in taking all the items on general and mental health from recent Eurobarometer surveys (References given in part 2 of Appendix A).

Hearing: Obviously, for a very demanding sound experiment, sufficient hearing ist essential to guarantee high quality data. Therefore, insufficient hearing was an exclusion criteria in the first step of selection. The hearing questions (B8_1 to B8_3, Appendix A) were borrowed from the large, EU-funded HYENA aircraft study (with Schiphol area involved). A planned, short screening test on hearing ability was eventually abandoned due to time constraints and concerns on the cognitive load of the respondents. It was also believed that by asking the 3 questions on hearing and by mentioning in the invitation letter the requirement of sufficient hearing would suffice. Furthermore, due to the substantial requirements posed by the experimental setup, it would be obvious at an early stage (training session) to the experimenter whether a participant could meet the hearing requirements.

Noise sensitivity: The relationship between noise sensitivity and annoyance is well established. Questionnaire studies show that, apart from noise exposure, noise sensitivity is a main explanatory factor of the variance in noise annoyance (Taylor, 1984; Job, 1988, 1991, 1999; Öhrström et al 1988; Fields 1993, Lercher 1996; Miedema & Vos 1999; Miedema & Vos, 2003; Botteldooren & Lercher 2004). There is a strong consensus that noise sensitivity constitutes a personality trait which is stable over time (Weinstein, 1978; Stansfeld et al 1985; Stansfeld, 1992; Zimmer and Ellermeier, 1999). Although the evidence for a sensory element in noise sensitivity is weak (Stansfeld 1992; Ellermeier, Eigenstetter & Zimmer, 2001) a judgemental component is well supported. Ellermeier, Eigenstetter & Zimmer (2001) found in their experiments noise sensitive participants to judge the same stimuli as louder and more unpleasant. Also Västfjäll (2002) showed recently that current experimentally induced mood interacted with noise sensitivity and had overall effects on annoyance and preference judgments of sounds. Therefore, there was good support to include a proper assessment of this non-acoustical factor in the postal selection questionnaire, as mentioned already in the original proposal.

Originally, it was intended to use the short version of the Zimmer/Ellermeier (1998) noise sensitivity questionnaire. However, no translated version was available and our main intention was to tap on the broader perspective of environmental sensitivity/vulnerability, which was suggested earlier by Weinstein (1980) and more recently also by Smith (2003). Therefore, we utilized single items for noise, air pollution and weather sensitivity with a standard 0 to 10 scale (B8_1 to B8_3, see Appendix A, part 2). These standard formats were used already in larger surveys and were shorter to answer for the potential participants. This format was also considered to be sufficiently valid for the use of the basic selection process in this study.

3.2. Selection procedure

3.2.1. Underlying ideas.

The participants in the experiments should thus be representative for the population under study on a number of *n* well-chosen criteria labeled with the index *i*. For each criterion different ranges may be selected. These ranges will be labeled using L_{ij}. There are several ways to approach this problem and we will discuss two of them in this document.

1. A selection based on the probability that a potential panelist with the given characteristics $X_i=L_{ij}$ is found in the reference population. E.g. assume that 12% of the population is highly sensitive to noise, has 2 children and is over 45, then the probability of a 50-year old father of two that is highly sensitive to noise should have a probability of selection of 0.12.

2. A selection based on the similarity of potential panelist *S* to the prototypical member of the population. E.g. assume the prototypical member of the population is highly sensitive to noise has no children and is over 45, then the 50 year old father of 2 that is highly sensitive to noise has less chance of being selected than the 60 year old single woman without children being very sensitive to noise.

A. Selection based on probability

Selection probability. Assume that a potential participant is characterized by $X_i=L_i$ for i=1,n. Then the probability of this person to be found in the population is $P(L_1, L_2, \dots L_n)$. This probability can be assumed equal to the percentage of the population with this combination of characteristics. Unfortunately, this probability is in general not known with acceptable accuracy if the number of criteria is more than a few. The reason for this is that the statistics of the population are derived from a finite size survey and this introduces a statistical error. Therefore statistical independence of the characteristics is assumed. Then the probability of a person to be found in the population is $P_1(L_1).P_2(L_2)\dots P_n(L_n)$. To further reduce the statistical error, a suitable grouping of answer categories is introduced.

Drawing from the pool of potential participants. For each potential participant we now have the probability of being selected. If the number of participants in the experiment, M, is huge, then random selection of subjects – taking into account this probability distribution – from an even larger pool of potential subjects would eventually lead to a distribution of participants that corresponds exactly to the reference population.

If only a small sample – compared to the number of possible combinations of criteria – can be drawn, random selection may not be the best choice. An example makes this obvious. Assume that only two subjects will participate in an experiment where gender is an important factor. If drawing at random there is a 0.25 probability to end up with two participants of the same sex. The experiment may benefit however from having one of each. An alternative technique is based on an iterative selection process. It starts by including the participant with the highest probability of being selected. Then the probability of selecting a subject with the characteristic already included through the first participant is reduced by 1/M. With these new probabilities the procedure is repeated. To illustrate the process, we again consider the two-participant experiment where gender matters. Assume a probability 0.51 of women in the population and a probability 0.49 for men. Thus the first participant will be a woman. Then the probability for selecting a woman is reduced to 0.01 so automatically the second participant selected is a man.

The drawing procedure described above only requires that the number of participants needed, M, is known prior to selecting the first participant.

Guaranteeing minimal representativity of the participants. Selection based on probability does not automatically include a method for deciding whether the selected participants are sufficiently representative for the population. It allows selecting the best M participants from a group of potential participants but it does not indicate if sufficient potential participants have been attracted.

By constructing the probability of a subject that is in the majority category for all of the criteria, one can get an estimate of the highest probability that can be expected. A minimal requirement of for example 1/10 of this maximum probability could be imposed, but such a choice is rather ad hoc.

B. Selection based on similarity to prototype member of population (Crisp)

Description of the typical member of the population. For each criterion, *i*, only two ranges are defined L_{i0} and L_{i1}. The majority of the population is in one of these ranges for each criterion. The typical member of the population is then described by the set of labels associated with the majority of the population e.g. {0, 1, 1, …0} where each zero or one refers to a range *L* for the i^th^ criterion.

Note that the definition of the typical member of the population is rather sharp. Looking back at the same example used above, the typical member is sensitive to noise, over 45 and has two children.

Selection of similar subjects from the pool of potential participants. Similarity can be measured in different ways. Calculating the (Pearson) correlation between the set of labels describing the typical member and the set of labels describing each of the potential participants is one option.

If only a small number of criteria are considered (*n* small), then this procedure is too harsh for selecting participants. An example makes this clear. Assume that only gender and number of children influences the experiment. The prototype member of the population may be female and without children because the majority of the population is female and has no children. If the participants are selected from a random group of e.g. 100 people based on the similarity to the prototype member, all participants will be female and without children. One can hardly say that this group of participants is representative for the population.

If the number of criteria considered is large (e.g. 30) than the number of possible combinations is so large (e.g. 2^{30}, assuming independence of the criteria) that it is impossible to fulfill all of them if only a small number of potential participants (e.g. a couple of hundreds) can be checked. The participants will not have the same property as the prototypical member of the population on a single criterion. The criterion will follow the prototype only slightly more. To what extend this will happen depends critically on the number of criteria, on the interdependence between the criteria, and the definitions of the answer ranges. This dependence is rather unpredictable, which makes the approach difficult to prove.

Guaranteeing minimal representativity of the participants. The selection of participants based on their similarity to a prototypical member of the population, allows for an absolute evaluation of the representativity of a potential participant more easily. If the similarity is one, a potential participant is clearly representative, if it is minus one, this potential participant is the opposite of the prototype member of the population.

A two-step selection procedure is useful. In a first step all potential participants that are sufficiently similar (e.g. correlation larger than zero) are selected. In a second step, the participants are drawn at random from this group. This procedure has the advantage that not only subjects with very high similarity are selected and thus on single criteria some subjects will deviate from the majority (e.g. also male subjects will be selected although the majority of the population is female).

C. Selection based on similarity to prototype member of population (Fuzzy)

Description of the typical member of the population. The disadvantages of the methodology described above, are caused by the crisp description of a prototype member of the population. E.g. it is rather contra-intuitive to say that the prototypical member of the population is over 45 years old because more than half of the population is over that age. It is precisely for these kinds of situations that fuzzy set theory has been introduced. A fuzzy set extends the binary coding of the prototypical member to a set of possible values for each criterion. E.g. the prototypical member could by older than 45 with possibility 1 while it is younger than 45 with possibility 0.9. At the same time it is possible to use more than two categories for each criterion (e.g. 5 age ranges). In fact, the ranges can be chosen using the same underlying thoughts as for the probability based selection.

In literature, several procedures can be found for obtaining the fuzzy set membership functions. The easiest one is a renormalization of the of the probability distribution which is – as described above – obtained from the distribution of subjects in the population over each of the criteria considered. This leads to a number of fuzzy sets $\pi_i(L_i)$ defined over the ranges chosen for criteria i.

Selection of similar subjects from the pool of potential participants. Each potential participant belongs to a particular category L_{ij} for each criterion X_i. To strictly adhere to the fuzzy set paradigm, this should be represented by a set containing L_{ij} only. Similarity between a potential participant and the prototype member of the population is not measured by fuzzy set similarity as one might assume at first sight but by containment. The containment of a potential participant that is in the range L_{ij} for criterion X_i. is simply $\pi_i(L_{ij})$. A good participant should be close to the prototypical member of the population on all criteria so an AND operation must be used to combine the criteria. Fuzzy set theory has different flavors of implementation of the and-operator. The more common one is the minimum operator: $\min_i(\pi_i(L_{ij}))$. It states that the participant is as good as his score on the worst criterion. This is quite radical. An alternative implementation of the and-operator uses the product (sometimes this is called the probabilistic implementation). Looking more closely at this latter implementation, one soon realizes that the probabilistic approach and the similarity to a prototype member of the population in its fuzzy variant turn out to give exactly the same ordering of potential participants. The only difference being that a potential participant that is in the majority category for all criteria now has a possibility of one for being representative.

Guaranteeing minimal representativity of the participants. As described above, selecting participants on the basis of their similarity to a fuzzy prototypical member of the population can correspond exactly to the probability based selection procedure. A small advantage is the theoretical background for renormalization that allows guaranteeing a minimal representativity of the participants. This also allows using a two-step selection procedure as described above. However, in this case the benefit in doing this is limited.

3.2.2 Selection Procedure used in this study

The selection procedure eventually chosen in this study, is a three stage process:

Stage 1. Subjects are first tested on absolute criteria of age (range [21,65]) and hearing abilities (no diagnosed hearing problem, no hearing aid).

Stage 2. From the remaining subjects only those that qualify as a *typical Dutch person* on the crisp, binary criterion (Pearson's correlation positive) based on the broad set of questions coded as given in Table 2, are retained.

Stage 3. The remaining candidates are then ranked by fuzzy resemblance to a *typical Dutch person* - a criterion that is very close to the probabilistic approach as described above - based on only a limited subset of questions for which being representative is of the utmost importance for the research conducted in this study. As this study was conducted in stages where at each stage new potential participants were approached, an absolute threshold of 0.01 was also considered for this last criterion. If no subjects with fuzzy resemblance to the *typical Dutch person* were available, additional questionnaires were distributed.

Table 2. Binary coding of the response to the questionnaire, with code for typical person in last column.

	How often do you hear noises (6 items, high-low 1-6 scale;5=no, 6=don't know)	
	Quantitative scale: left-hand categories "more often" (Coded 1),	
	right-hand categories "less often, no, don't no" (Coded 0).	
Q12 I1	52 % said No (calculated out of ca. 1010+612=1622 taken from B1–3 though)	
	Our *response format different* ([high] 1-6 [low,no]), split between 1,2,3,4 (Minority 1) and 5,6 (Majority 0)	**0**
Q12 I2	88% said No (out of ca 226 taken from B1_3 though)	
	Our *response format different* ([high] 1-6 [low,no]), split between 1,2,3,4 (Minority 1) and 5,6 (Majority 0)	**0**
Q12 I3	89% said No (out of ca 200 taken from B1_3 though)	
	Our *response format different* ([high] 1-6 [low,no]), split between 1,2,3,4 (Minority 1) and 5,6 (Majority 0)	**0**
Q12 I4	69% said No (categories 5,6)	
	Identical response format, split between 1,2,3,4 (Minority 1) and 5,6 (Majority 0)	**0**
Q12 I5	52% said No (category 5,6)	
	Identical response format, split between 1,2,3,4 (Minority 1) and 5,6 (Majority 0)	**0**
Q12 I6	54% said yes, daily + at least 1x per week	
	Identical response format, split between 1,2 (Majority 1) and 3,4,5,6 (Minority 0)	**1**
	How much annoyed last 12 months (6 items, 0-10 scale; 0=not annoyed, low-high 1-10)	
	Quantitative scale: left-hand categories "no, less annoyed" (Coded 0),	
	right-hand categories "more to less annoyed" (Coded 1).	
Q13 I1	51.5% (out of 612 +1010= 1622) are in categories 0,1,2,3.	
	Split between ≤3 (Majority 0) and ≥4 (Minority 1)	**0**
Q13 I2	53% (out of 226) are in catetory 0,1,2,3.	
	Split between ≤3 (Majority 0) and ≥4 (Minority 1)	**0**
Q13 I3	57% (out of 200) are in category 0,1,2,3,4	
	Split between ≤4 (Majority 0) and ≥5 (Minority 1)	**0**
Q13 I4	51% said Catgories 1-10	
	Split between 0 (Minority 0) and ≥1 (Majority 1)	**1**
Q13 I5	52% said Catgories 2-10	
	Split between 0,1 (Minority 0) and ≥2 (Majority 1)	**1**
Q13 I6	52% said Catgories 2-10	
	Split between 0 (Minority 0) and ≥1 (Majority 1)	**1**
	Sleep disturbed last 12 months (6 items, 0-10 scale; 0=not disturbed, low-high 1-10)	
	Quantitative scale: left-hand categories "no, less disturbed etc." (Coded 0),	
	right-hand categories "very, decreasing distrubed" (Coded 1).	
Q14 I1	68-79% (out of ≈ 1500) said Category 0	
	Split between 0 (Majority 0) and ≥1 (Minority 1)	**0**
Q14 I2	68-79% (out of ≈ 1500) said Category 0	
	Split between 0 (Majority 0) and ≥1 (Minority 1)	**0**
Q14 I3	68-79% (out of ≈ 1500) said Category 0	
	Split between 0 (Majority 0) and ≥1 (Minority 1)	**0**
Q14 I4	75% (out of 651) said Category 0	
	Split between 0 (Majority 0) and ≥1 (Minority 1)	**0**
Q14 I5	74% (out of 986) said Category 0	
	Split between 0 (Majority 0) and ≥1 (Minority 1)	**0**
Q14 I6	66-72% (out of ≈1000) said Category 0	
	Split between (Majority 0) and ≥1 (Minority 1)	**0**

	Type of living environment (9 items, only "yes"-response, several possible)	
	Nominal scale of 9 items.	
Q15	56% (out of 2076) responded yes to Item 1-3 (Majority 1); yes to Item 4-9 (Minority 0)	
	If 1, 2, or 3 code 1, else 0	**1**
	Extent of "noise sensitivity" or "feel afraid" (1 item for each: "0–not at all", [low]1-10 [high], "11–don't know" (wn called 11)	
	Quantitative scale: left-hand categories "don't know, no, less disturbed etc." (Code 0) and "more disturbed" (Code 1)	
Q22	51% (out of 2076) said Category 5-10	
	Split between "11–don't know, 0–no, ≤4" (Minority 0) and ≥5 (Majority 1)	**1**
Q23	64% (out of 2076) said Categories 11, 0, ≤2	
	Split between "11–don't know, 0–no, ≤2" (Majority 0) and ≥3 (Minority 1)	**0**
	Environmental Factors (9 items, bipolar scale [bad]0,1,2,3,4 [5–not bad not good], 6,7,8,9,10[excellent]; 11–nvt, 12–wn	
Q16 I1	Traffic safety, 54% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q16 I2	Social safety, 69% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q16 I3	Odor, 59% (out of 2076) said Category 8-10 (Majority 1)	**1**
Q16 I4	Factory noise, 55% (out of 2076) said Category 11(nvt) (Majority 0)	**0**
Q16 I5	Traffic noise, 52% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q16 I6	Soil pollu., 58% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q16 I7	Dust/industry, 53% (out of 2076) said Category 11(nvt), 12(wn), 5(neutrl) (Majority 0)	**0**
Q16 I8	Water, 53% (out of 2076) said Category 6-10 (Majority 1)	**1**
Q16 I9	Waste, 56% (out of 2076) said Category 7-10 (Majority 1)	**1**
	Total quality of neighborhood environment (see previous)	
Q17	79% (out of 2076) said Categories 7-10 (Majority 1), thus, 11–wn, 0, 1-6 is Minority (0)	**1**
	Satisfaction (Contentness) with living situation	
	(1 item for each: "0–not at all", [low]1-10 [high], "11–nvt", "12–don't know(wn)"	
	Quantitative scale: left-hand categories "nvt, don't know, no, less content etc." (Code 0) and "more content" (Code 1)	
Q18 I1	Dwelling, 75% (out of 2076) said Category 8-10 (Majority 1)	**1**
Q18 I2	Clean neighb , 69% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q18 I3	Space play, 63% (out of 2076) said Category 0-7,11,12 (Majority 0)	**0**
Q18 I4	Density build., 67% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q18 I5	Friendl/neigh, 53% (out of 2076) said Category 8-10 (Majority 1)	**1**
Q18 I6	Env situation, 69% (out of 2076) said Category 7-10 (Majority 1)	**1**
Q18 I7	Facilities, 83% (out of 2076) said Category 11(nvt), 12(wn), 0-8 (Majority 0)	**0**
Q18 I8	Green areas, 53% (out of 2076) said Category 8-10 (Majority 1)	**1**
Q18 I9	Pub.Transport, 57% (out of 2076) said Category 11(nvt), 12(wn), 0-6 (Majority 0)	**0**
Q18 I10	Maintenance, 64% (out of 2076) said Category 11(nvt), 12(wn), 0-7 (Majority 0)	**0**
Q18 I11	Car parking, 59% (out of 2076) said Category 11(nvt), 12(wn), 0-7 (Majority 0)	**0**
	Type of house you live in (8 items, only "yes"-response, only one possible answser)	
	Nominal scale of Item 1-8, of which Item 8 is wn	
Q1	79% (n= 2076) responded yes to Items 2,3,4,5,6 (Majority 1); yes to Items 1,7,8 (Minority 0)	**1**
	Own, rent home	
Q2	67% said "yes" to Item 2. Your property (Majority 1)**,** yes to Items 1,3,4 (Minority 0)	**1**
	Age of respondent (continuous in years)	
Q3	60% (out of 2057) were 16-24 or 45->65 years (Majority 0), 25-54 years (Minority 1)	**0**
	Gender (2 items, "yes"-response)	
Q4	gender woman (Majority 1), man (Minority 0)	**1**
	Civil status (5 items, "yes"-response)	

Q5	65% married or ‘sustainably’ living together (Item 1) = (Majority 0) “yes”-response to Items 2,3,4,5 = (Minority 1)	**0**
Q6	**Number of persons in familiy (number, plus number of which <15 years)** 57% (out of 2076) said 1 or 2 persons in family (Majority 1), ≥3 persons (Minority 0)	**1**
Q7	**Highest level of eductiaon finished (select one)** **(10 items, only “yes”-response, Item 10=wn)** 51% responded “yes” to Items 5 and 7 (Majority 1), “yes” response Items 1-4, 6, 8-10 (Minority 0)	**1**
Q8	**Work/study/unemployed/handicapped/etc.** **(10 items, only “yes” response, Item 10=wn)** 52% responded “yes” to Items 1and 5 (Majority 0), “yes”-response Items 2-4, 6-10 (Minority 1)	**0**

The process of selecting panelist was performed in different selection rounds because it was not clear what the initial response would be, because it was foreseen that a more targeted recruitment may be required, and because we wanted to keep the time between answering the questionnaire and participation as short as possible to limit drop-out. Figure 4 gives an overview of the different selection rounds. Initially, 500 questionnaires were personally administered at the doorstep to people’s homes. In order to collect potential participants that fulfill the different criteria, the survey was distributed approximately equally to the proportions in the Dutch population on the four criteria: house type, rural/urban, close to railway, close to road. Unfortunately, the questionnaires were send back rather slowly and international mail took more time than expected so only approximately 50 potential panelists were available at the start of the experiment (selection round 1). Figure 4 shows the fraction of these panelists that had to be removed based on the first two selection criteria. It was decided that another round of 500 questionnaires was needed, but unfortunately only 200 got distributed. This brought us to selection round 2. As it became obvious that it would be difficult to get enough panelists in some categories using the selected distribution strategy (in particular women aged around 40), distribution of questionnaires via the panelists that participated to the experiment was started by asking them to urge their friend to send in a questionnaire as well. Simultaneously approximately 600 more questionnaires were personally administered at the doorstep to people’s homes. This brought the total number of questionnaires distributed to 1300. In order to increase response further - in particular in the population representative categories that were underrepresented - 200 questionnaires were personally administered at market places and important shopping areas to only those visitors who stated their intention to participate. Early after these new initiatives enough additional potential panelists were known to start selection round 3 and 4. A week later additional potential panelists had send in their questionnaire and selection round 5 could be made. All potential participants were given envelopes with port paid by recipient which they were to mail back to Ghent University.

Since the different waves of distribution of questionnaires overlapped, it is only possible to give an impression of the overall response. Out of a total of 1500 questionnaires distributed, about 300 positive (those willing to participate) responses were received. Unfortunately 45 came in after the end of the experiment. The positive response rate was 20 %. In addition about 50 denials were received.

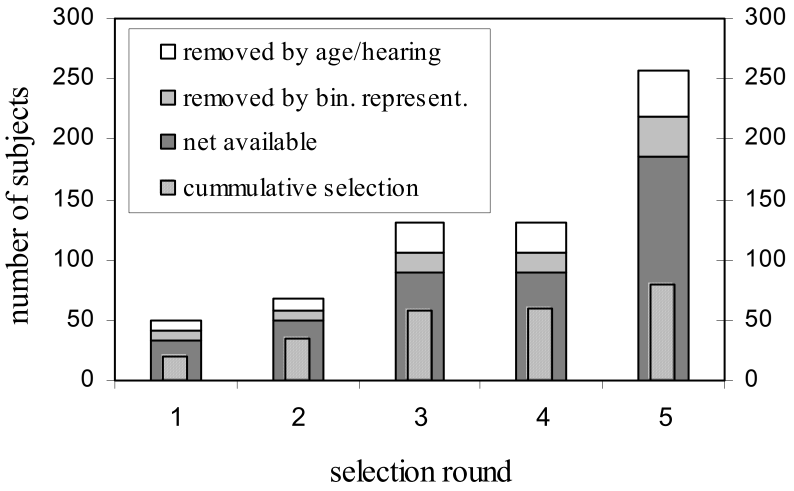


Figure 4. Number of potential panelists available for the experiment split into the number of them rejected by the age criterion and the requirements on hearing (open bar), number of them rejected due to the criterion on general representativity (binary) (light gray bar), and the remaining net available number (dark gray bar); also shown is the number of panelists selected (dashed bar) at each selection round of the project.

Stage 3 of the selection procedure (see above) is an iterative procedure: each time a participant takes part in the experiment the selection probability of those that resemble him/her is reduced accordingly. This iterative selection procedure could not be enforced strictly because of several reasons: (1) some participants are not home when we try to contact them, and it is obviously not possible to wait for this "best participant" before calling the second best; (2) some participants agree to come on a particular date and time but eventually don't show up or let us know that they no longer want to participate. Therefore the selection was made in groups of about 20 panelists each round. That is, the 20 best participants are selected (all fulfilled the Stage 1 and 2 criteria, dark gray bars in Figure 4), each of them is contacted and booked for a particular date and then the panelists who were actually participating are taken into account when selecting the next group of potential participants.

3.3. Analyses of the participants

To validate the selection procedure described above, the distribution of the participants over different values of the selection criteria applied to the questionnaire responses that are guaranteed by stage 3 of the selection procedure are given in Figure 5. Note that we are testing representativity against the RIVM and Eurobarometer questionnaire results and thus the resulting panel will be at best as representative for the Dutch population as these surveys were.

General demographic criteria are included because it is not unlikely that these may influence the way people react to noise and also because a result based only on a particular subgroup (e.g. young man) is not socially acceptable.

- Age. Selection stage 3 guarantees distribution in 10-year wide age categories. Although the percentages are generally higher because we include only panelists between 21 and 65 in the listening experiment, the agreement is very good.

- Gender. Mainly because much more men initially expressed their interest in participating in the experiment, there is a very slight unbalance between panelists and Dutch population.

- Education. The labels refer to: {Geen opleiding, Lagere school, Lager beroepsonderwijs (bijv LTS, huishoudschool), MAVO (of Mulo), Middelbaar beroepsonderwijs, HAVO/VWO (of HBS/Gymnasium/MMS), Hoger beroepsonderwijs, Wetenschappelijk onderwijs (universiteit)}. Selection stage 3 guarantees the distribution between the subgroups {1,2,3}, {4,5,6}, and {7,8} only to make sure not to much effort is wasted trying to be distinguish between similar types of education. According to this view the unbalance between education level 2 and 3 and between 4 and 5 is acceptable.

Some personal characteristics (traits) have been proven to influence the perception of noise annoyance. These were therefore included as important selection criteria.

- Noise sensitivity. Selection stage 3 tried to guarantee the balance between the extremes {0}, {10}, and the ranges below average {1,2,3,4} and above average {5,6,7,8,9}. This did not succeed for the category {0}; the number of not at all noise sensitive people amongst the participants is lower than the Dutch average.

- Feeling afraid or frightened. Selection stage 3 tried to guarantee the balance between the extremes {0}, {10}, and the ranges below average {1,2} and above average {3,4,5,6,7,8,9}. This did not succeed for the category {0}; the number of people never feeling frightened amongst the participants is lower than the Dutch average.

Experiencing noise at home may influence the way participants react to the noise they are exposed to. In particular, since we are studying train noise, it may be relevant whether people hear train noise at home. Adding additional noise sources may broaden the focus and thus give relatively less weight to the most relevant criteria. It may also be relevant how the participants react to that particular noise or how the participants experience the quality of their living environment in general.

- Hearing train noise. Selection stage 3 tries to guarantee the balance between people that hear train noise every day or once a week and those that hear train noise less often or never. It turns out that the selection is quite good (Figure 5) which may also be partly due to the way the questionnaires are distributed. If they are in the initial population, the selection procedure gets the best participants out.

- Quality of the traffic noise in the living environment. Selection step 3 tries to guarantee the balance between below average (<5) and above average (>4). A slight unbalance towards the better quality is observed in the participants, probably because the traffic situation is in general quite reasonable in the area where the panelists were recruited.

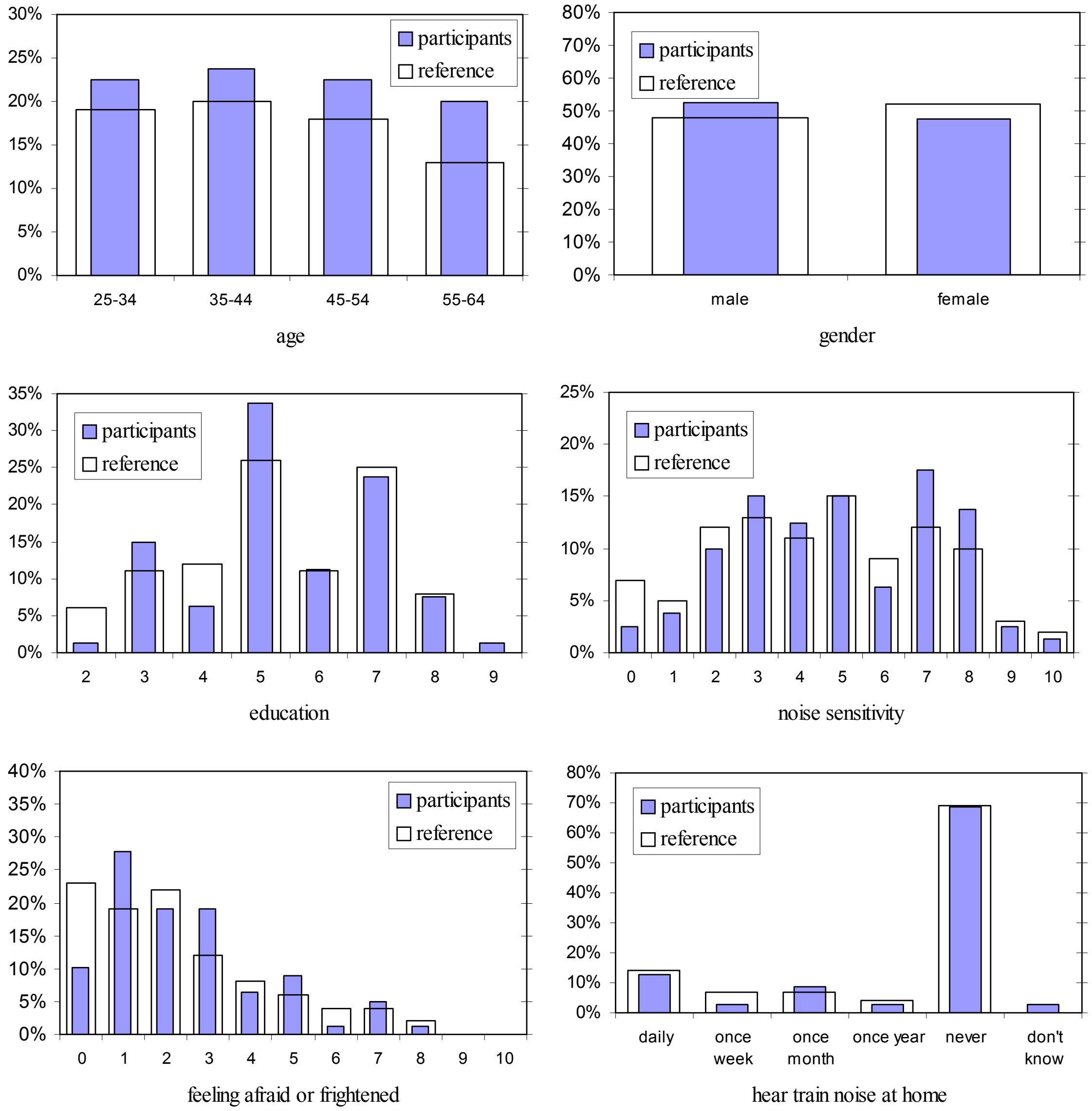
- Quality of the living environment. Selection stage 3 tries to guarantee the balance between below average (<7) and above average (>6). Although there is a shift towards high quality living environments among the participants, this shift is above the division used to guarantee that sufficient panelists have a poor quality living environment.

Finally, a person’s health may influence the way he or she reacts to an experiment like the one that is being done here. Therefore two questions on health are considered.

- General health. Selection stage 3 tried to guarantee the balance between very good and good on the one hand and fair to very bad on the other hand. This only partly succeeded as can be seen from Figure 5. It seems that the people that responded positively to the call for participation in the experiment, were in good health so it was difficult for the selection process to find unhealthy ones.

- Illness. Selection stage 3 tried to keep the balance between people having a long standing illness or health problem and those that don’t have such a problem. Again, the selection did not succeed in finding enough people with such an illness, which is quite reasonable since we do not expect these people to volunteer for the experiment.

It can be concluded in general that the participants are representative for the Dutch population on most of the criteria of relevance and that in those cases where there is some deviation, this deviation is not very big.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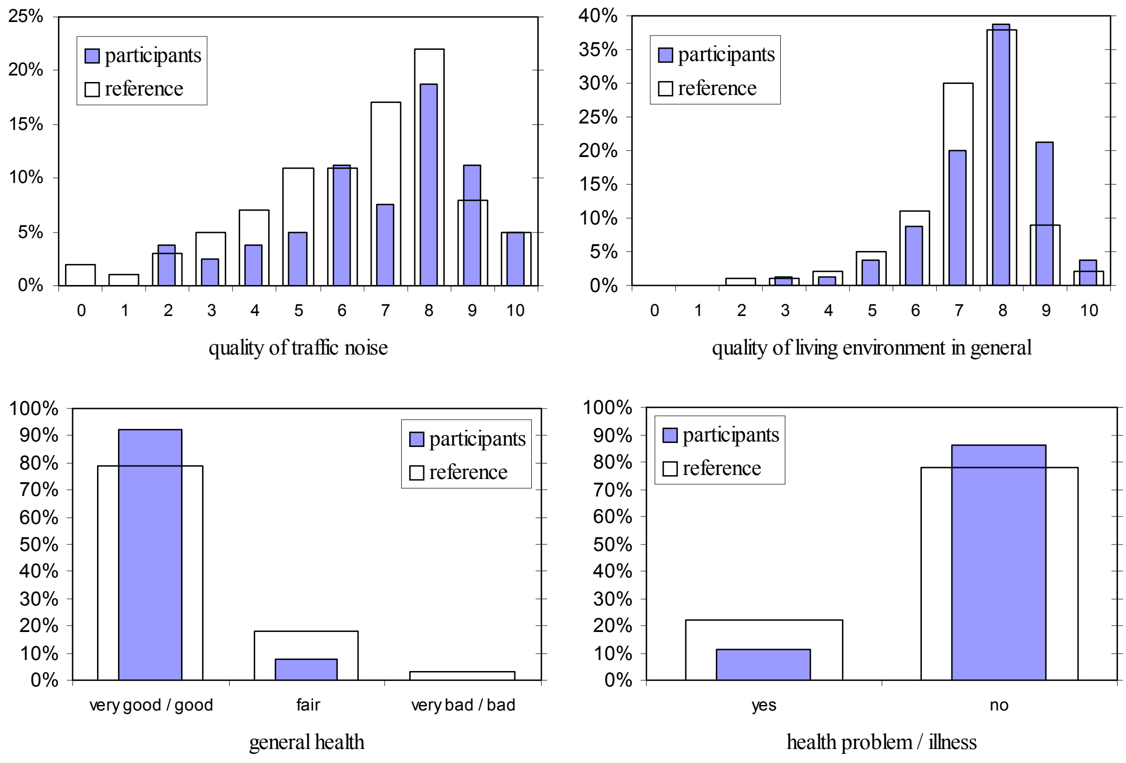


Figure 5. Distribution of panelists in the listening experiment over different questionnaire response categories on the most relevant criteria, compared to the distribution of the Dutch population (reference).

4. The sound samples

4.1. Recording of sound samples

Measurement setup

To achieve a good 3D sound reproduction of the passages at the test house, the sound was registered simultaneous by 2 microphones, seperated 20 m from each other parallel to the track. A preliminar playback test showed this distance was large enough (see Section 5). At the same time a binaural recording was made, which serves as a fall-back option only, since this was not strictly required for the listening experiment. Because the recordings had to be made at 4 distances, it was decided to have 2 different recording chains to be able to record at 2 distances at the same time. Both setups are independent, which gave us some backup in case of equipment failure on location.

Figure 6 gives an overview of both recording setups. In setup A the B&K Pulse system is used, together with four B&K 4189 0V free field microphones, supplying a 4-channel recorded signal. Two microphones are mounted on a tripod at a height of 1.5 m above the ground level, 20 m separated from each other. In the middle a B&K 4100 binaural head is placed on a seat, which carries the other two microphones. In setup B a Dolch NPAC-Plus P111 portable computer combined with a LynxTwo C PCI sound card was used, together with four B&K 4190 200V free field microphones. The signals from the two separated microphones were amplified by two B&K 5935 amplifiers, the two signals from the binaural head by a B&K 2672 conditioning amplifier. Figure 8 (a) shows a picture of setup A in the field.

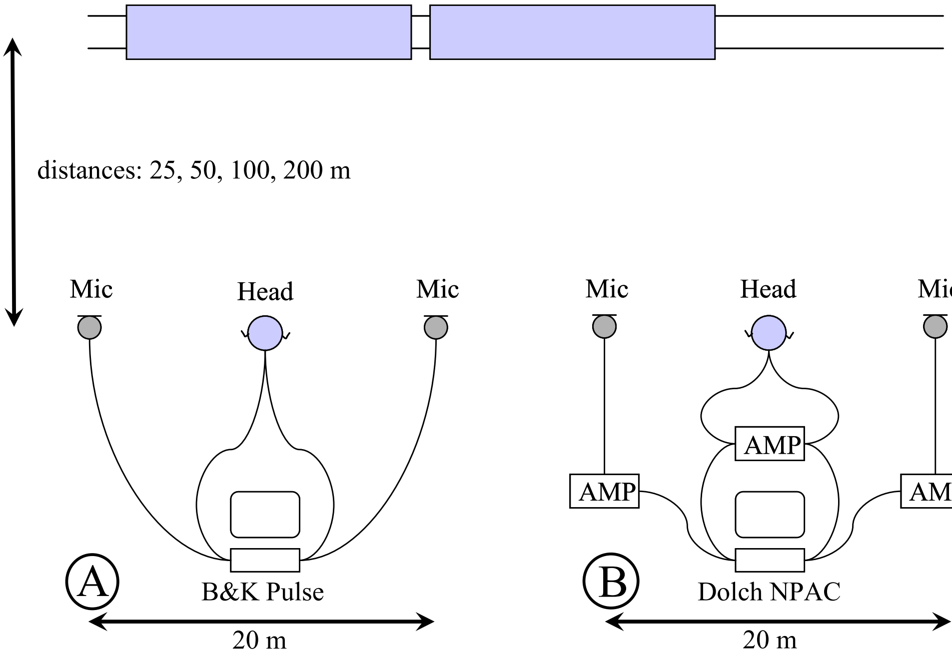


Figure 6. The two recording setups.

Measurement locations and times

A good recording location should meet some basic requirements, both acoustical and practical. The background noise, in absence of trains, should be as low as possible. There should be no obstacles between the train track and the recording setup, up to 200 m from the track. Therefore, measurement in agricultural fields located next to train tracks in rural area seemed the best solution. To have a power source in the neighbourhood would also be an advantage, since not all of our equipment could run for a long time on batteries.

Table 3 shows the recording dates and locations chosen. At all sites, the basic requirements were met. The TGV trains at high speed were recorded in Beloeil (in Belgium close to Ath), which is near the TGV connection between Brussels and Calais (France). Dutch IC trains of the new type (duplex) were measured in Oudenbosch near Roosendaal; on the same spot the TGV travelling at low speed from Brussels to Rotterdam could be measured. At the test track in Lathen (Germany), we measured the Transrapid 8 Maglev train at 3 different speeds. Passages at approx. 200 km/h and 400 km/h were measured near post 172, along the straight part of the track; passages at approx. 300 km/h near post 472, along the northern loop of the track. Figure 7 shows the background noise spectrum and total level at the 4 different train measurement locations. All recordings were made in open field without noise barriers.

Table 3. Measurement dates and locations

Type of sound	**Recording date**	**Location**	**Coordinates**	**Track height**
Highway	19/10/2004	E40 Zwijnaarde, Belgium	N 51°01’47” E 4°43’40”	≈ 0.5 m
TGV (high speed)	26/10/2004	Beloeil, Belgium	N 51°34’26” E 4°43’01”	≈ 1 m
IC, TGV (low speed)	03/11/2004	Oudenbosch, The Netherlands	N 52°36’14” E 5°34’43”	≈ 1 m
Maglev	09/11/2004	Lathen, Germany	N 53°54’46” E 7°22’36”	≈ 6 m

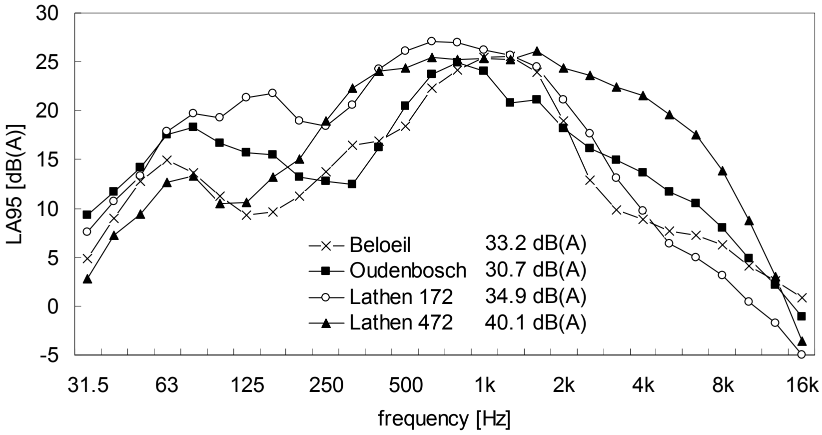


Figure 7. L_{A95} at the different measurement locations, as an estimate of the background level.

For the recording of the highway sound the acoustical requirements are not so strict, because this is a continuous source; the highway at different distances was measured on the Ghent University campus at Zwijnaarde, which is close to the E40 highway between Brussels and Ostend (Belgium). Figure 8 (b) to (d) show a picture of the different types of trains recorded. Local road traffic sounds were also recorded for additional experiments, near the region of Ghent (Belgium).

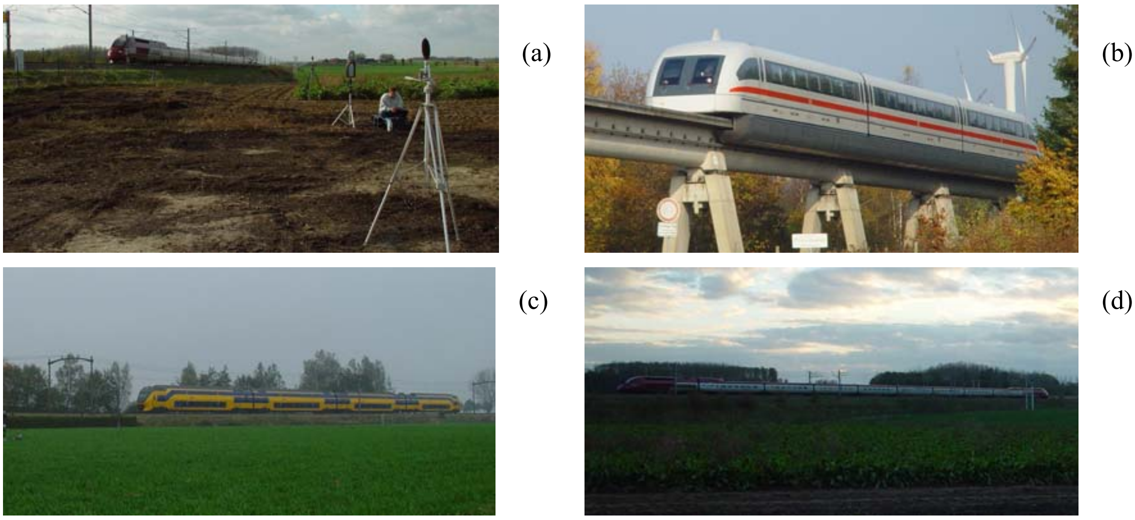


Figure 8. (a) The first recording setup; (b) The Maglev train; (c) A Dutch IC train; (d) A TGV train.

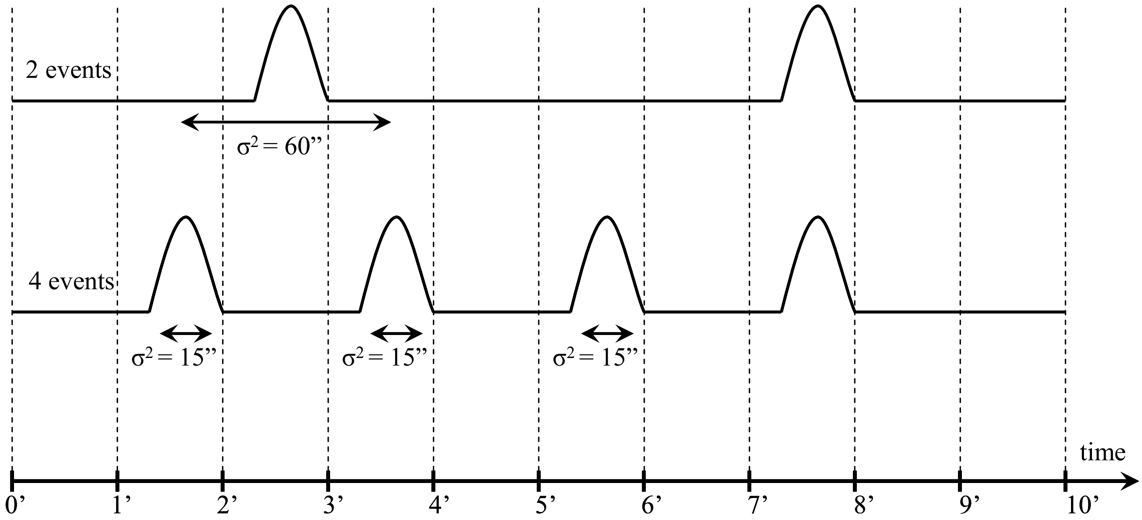


Figure 9. Construction of 10-minute excerpts from 45-second passages.

4.2. The experimental sounds

Construction of 45-second and 10-minute excerpts for the experiment

On all measurement sites and at all distances from the track, a continuous sound recording was made, spanning several train passages (or about half an hour in case of the highway sound). Afterwards the train passages and highway sound excerpts of best quality were selected and cut out. For the trains, a frame of 45 seconds around the sound level peak was used; this ensures that the train sound level is less than the background sound level at the recording site in the beginning and at the end of the passage. All sounds were then calibrated to 110 dB rms corresponding to -6 dB rms in the sound file. Finally on all 45-second fragments a 5-second fade-in and fade-out was applied. In particular, this makes the highway sound not to start and end too abruptly.

Consequently, 10-minute sound excerpts or menus were prepared for use with the listening experiments. For the train noises, these were created by playing the same 45-second fragment at certain moments in time. It was decided to have 2 or 4 identical events in 10 minutes. Figure 9 shows the time schedule of both possibilities. The last event will always be played at 7’15”, which ensures that all excerpts have 2’ of silence at the end. The first 1 or 3 events will not always be played at the same time; the starting time can vary with a standard deviation of 60 or 15 seconds respectively.

For the experiments, a continuous highway sound, recorded at 50 m from the road, with a duration of 8’ and a silent period of 2’ at the end was also created. Local road traffic recordings of 8’ were alse done for the additional experiments.

Overview of levels (L_{Aeq}, ASEL, N)

Table 4 to Table 7 give an overview of the acoustical levels associated to the 45-second fragments. For the train noises, the sound exposure level (ASEL) is given; for the road traffic noises the equivalent sound level ($L_{Aeq,45sec}$) is given. For all fragments the Zwicker loudness (N) is also added. Table 8 to Table 9 show the acoustical levels associated to the 10-minute road traffic fragments.

For the Maglev sounds, the ASEL levels are comparable with the levels used by (Vos, 2004), at least for distances up to 100 m from the track. At 200 m, the levels are about 5 dB(A) lower than used in (Vos, 2004). For the TGV trains the levels are higher; the difference increases with the distance from the track to about 8 dB(A) at 200 m. In contrast, the IC train levels are on the average about 10 dB(A) lower, because only the new type IC trains, which are more quiet, were measured in this study. It should be mentioned that the level of the IC train at 25 m is lower than the level at 50 m. This is due to the fact that the selected sound fragments do not necessary originate from the same train passage, and that there is a natural spread on the speed and the number of wagons of the trains at different passages. At 25 m, an ASEL level of about 88 dB(A) should be expected for a typical modern dutch IC train.

Table 4. ***Sound exposure level (ASEL)*** *in free field for one-train passages (45 seconds) of Maglev, TGV and IC trains, expressed in dB(A).*

Speed/Distance	25 m	50 m	100 m	200 m	**Range (distance)**	**Total range**
MAGLEV: 190, 209, 190, 190 km/h	80.1	72.9	71.3	59.7	**20.4**	
MAGLEV: 306, 304, 302, 305 km/h	86.3	83.0	80.3	69.6	**16.7**	
MAGLEV: 389, 390, 393, 395 km/h	92.6	88.7	85.2	70.4	**22.2**	
Range (speed)	**12.5**	**15.8**	**13.9**	**10.7**		**32.9**
TGV: ≈ 140 km/h	84.1	78.3	73.6	64.4	**19.7**	
TGV: ≈ 300 km/h	92.8	90.6	86.9	83.0	**9.8**	
Range (speed)	**8.7**	**12.3**	**13.3**	**18.6**		**28.4**
IC: ≈ 140 km/h	75.0	80.9	72.4	62.0	**18.9**	
Range (speed)	**0.0**	**0.0**	**0.0**	**0.0**		**18.9**
Total range (speed)	**17.8**	**17.7**	**15.6**	**23.3**		

1) The Maglev train speeds are listed in order of increasing distance to the track.

2) To obtain the levels at the façade, add 1.0 dB(A). To obtain the corresponding $L_{Aeq,45sec}$ levels, subtract 10LOG(45) = 16.5 dB(A). The dB(A) ranges remain the same.

3) For corresponding 2-train and 4-train passages $L_{Aeq,10min}$ values, subtract 8.2 dB(A) and 5.2 dB(A) respectively, from the corresponding $L_{Aeq,45sec}$ values. For corresponding ASEL values add 3 dB(A) and 6 dB(A) respectively.

4) The level of the IC train at 25 m is lower than the level at 50 m. This is due to the fact that the selected sound fragments do not necessary originate from the same train passage, and that there is a natural spread on the speed and the number of wagons of the trains at different passages. Recordings were made at locations with a good track condition.

Table 5. ***Zwicker loudness (N)*** *in free field for one-train passages (45 seconds) of Maglev, TGV and IC trains, expressed in sone.*

Speed/Distance	25 m	50 m	100 m	200 m	**Range (distance)**	**Total range**
MAGLEV: 190, 209, 190, 190 km/h	18.3	11.6	10.7	4.8	**x 3.8**	
MAGLEV: 306, 304, 302, 305 km/h	26.4	20.6	16.3	9.1	**x 2.9**	
MAGLEV: 389, 390, 393, 395 km/h	41.1	32.7	24.7	9.8	**x 4.2**	
Range (speed)	**x 2.2**	**x 2.8**	**x 2.3**	**x 2.0**		**x 8.6**
TGV: ≈ 140 km/h	23.4	15.9	11.2	6.7	**x 3.5**	
TGV: ≈ 300 km/h	43.8	37.2	28.6	21.9	**x 2.0**	
Range (speed)	**x 1.9**	**x 2.3**	**x 2.6**	**x 3.3**		**x 6.5**
IC: ≈ 140 km/h	14.1	17.4	10.3	5.3	**x 3.3**	
Range (speed)	**x 1.0**	**x 1.0**	**x 1.0**	**x 1.0**		**x 3.3**
Total range (speed)	**x 3.1**	**x 3.2**	**x 2.8**	**x 4.6**		

1) Zwicker loudness based on two simultaneous microphone recordings.

Table 6. ***Equivalent sound level ($L_{Aeq,45sec}$)*** *in free field for 45-second road traffic sounds, expressed in dB(A).*

Intensity/Distance		25 m	50 m	100 m	200 m	**Range (distance)**
Highway free flow road traffic		71.6	66.1	62.6	55.3	**16.3**
Local road traffic	Low intensity, at 10 m	62.4				
	Low intensity			58.6		
	Medium intensity, at 10 m	63.2				
	Medium intensity			62.3		
	High intensity, at 15 m	73.7				
	High intensity			65.7		
Range (intensity)		**11.3**		**7.1**		

1) The local road traffic noises were for the additional listening experiments only.

2) To obtain the levels at the façade, add 1.0 dB(A). To obtain the corresponding ASEL levels, add 16.5 dB(A). The dB(A) ranges remain the same.

Table 7. ***Zwicker loudness (N)*** *in free field for 45-second road traffic sounds, expressed in sone.*

Intensity/Distance		25 m	50 m	100 m	200 m	**Range (distance)**
Highway free flow road traffic		25.9	18.6	15.7	9.9	**x 2.6**
Local road traffic	Low intensity, at 10 m	15.1				
	Low intensity			12.0		
	Medium intensity, at 10 m	15.4				
	Medium intensity			15.2		
	High intensity, at 15 m	31.6				
	High intensity			19.8		
Range (intensity)		**x 2.1**		**x 1.7**		

1) The local road traffic noises were for the additional listening experiments only.
2) Zwicker loudness based on two simultaneous microphone recordings.

Table 8. ***Equivalent sound level ($L_{Aeq,10min}$)*** *in free field for 10-minute road traffic sounds, expressed in dB(A).*

Intensity/Distance		25 m	50 m	100 m	200 m	**Range (distance)**
Highway free flow road traffic			65.3			**0.0**
Local road traffic	Low intensity, at 10 m	61.5				
	Low intensity			59.6		
	Medium intensity, at 10 m	62.1				
	Medium intensity			61.5		
	High intensity, at 15 m	70.9				
	High intensity			61.2		
Range (intensity)		**9.4**		**1.9**		

1) The local road traffic noises were for the additional listening experiments only.
2) To obtain the levels at the façade, add 1.0 dB(A). To obtain the corresponding ASEL levels, add 27.8 dB(A). The dB(A) ranges remain the same.

Table 9. ***Zwicker loudness (N)*** *in free field for 10-minute road traffic sounds, expressed in sone.*

Intensity/Distance		25 m	50 m	100 m	200 m	**Range (distance)**
Highway free flow road traffic			17.4			**x 1.0**
Local road traffic	Low intensity, at 10 m	14.2				
	Low intensity			13.4		
	Medium intensity, at 10 m	15.2				
	Medium intensity			14.8		
	High intensity, at 15 m	27.0				
	High intensity			14.4		
Range (intensity)		**x 1.9**		**x 1.1**		

1) The local road traffic noises were for the additional listening experiments only.
2) Zwicker loudness based on two simultaneous microphone recordings.

Construction of master scaling sounds

For the generation of the 7 master scaling sounds, the 45” fragment of highway noise recorded at a distance of 50 m from the road was used as a reference. A filter which attenuates the sound at frequencies below 500Hz by 3dB and above 500Hz by 6 dB was applied 3 times to produce 3 extra sounds with varying level, all below the level of the reference highway sound. In the same way, a filter that amplifies the sound at frequencies below 500hz by 3 dB and above 500Hz by 6 dB was used to generate 3 master scaling sounds with varying level higher than the level of the reference highway sound. Table 10 summarizes the acoustical levels associated to these 7 master scaling sounds.

Spectral and temporal characteristics

Figure 10 shows the sound exposure level (ASEL) in 1/3-octave bands in the free field for the one-train passages. Figure 11 shows the equivalent sound level of the 45-second master scaling sounds and road traffic sounds. In appendix D one can find $L_{Aeq,1sec}$ time-frequency plots of all 45-second one-train passages.

Table 10. **Equivalent sound level ($L_{Aeq,45sec}$)** *and* **Zwicker loudness (N)** *in free field for 45-second master scaling sounds.*

Label	$L_{Aeq,45sec}$ [dB(A)]	N [sone]
L1	52.6	7.6
L2	56.8	10.2
L3	61.4	13.7
L4 (= highway at 50 m)	66.1	18.6
L5	71.7	25.5
L6	77.4	34.8
L7	83.2	47.8
Range	**30.6**	**x 6.3**

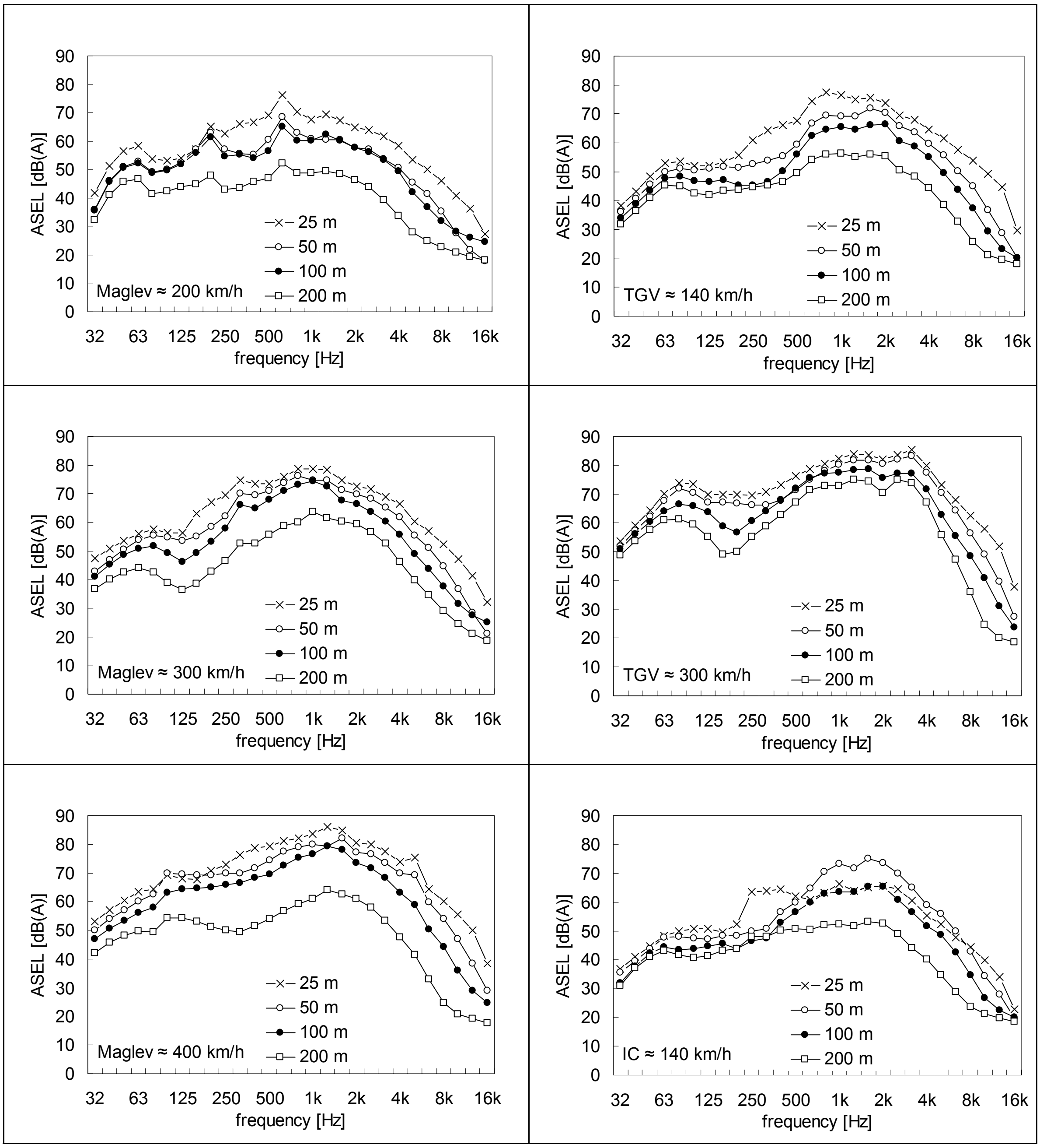


Figure 10. ***Sound exposure level (ASEL) in 1/3-octave bands*** *in free field for one-train passages (45 seconds) of Maglev, TGV and IC trains, expressed in dB(A). For each driving speed, 4 spectra are shown, corresponding with the 4 distances of measurement.*

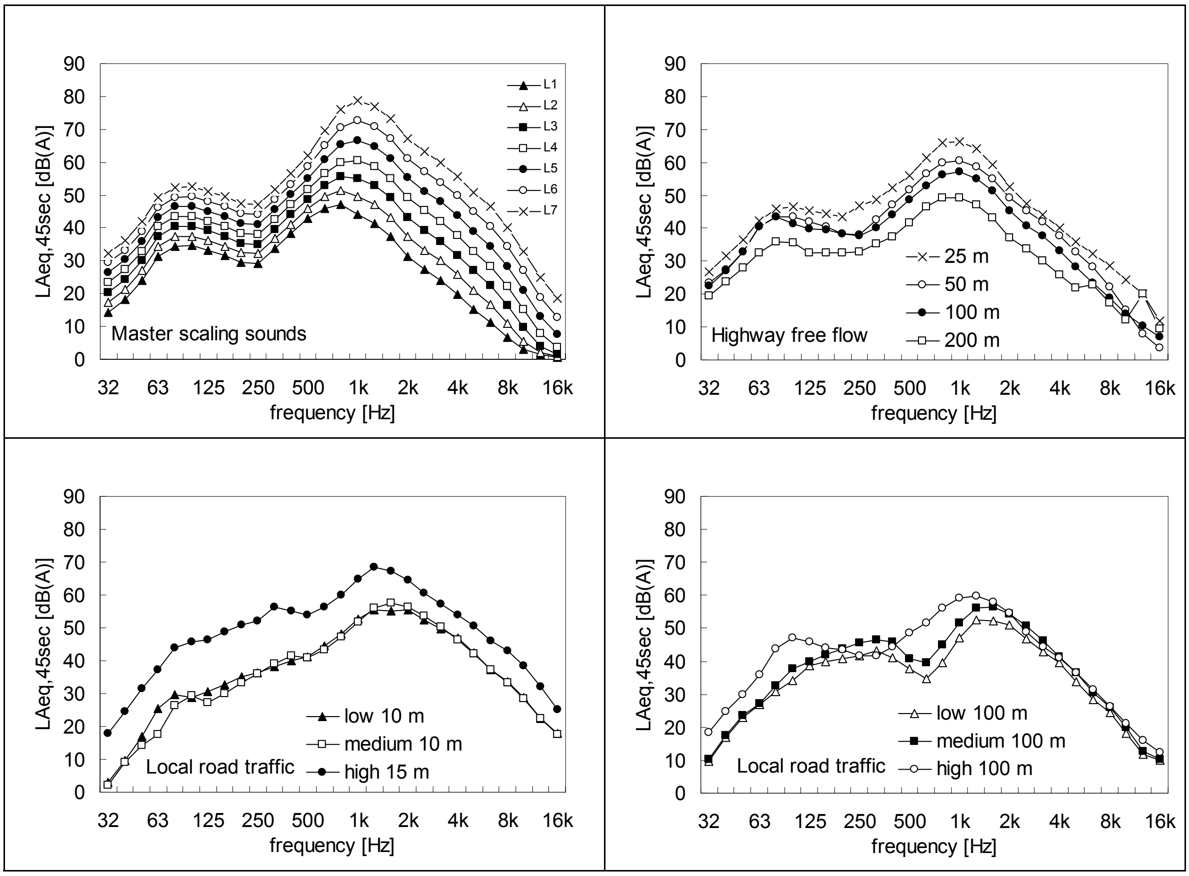


Figure 11. **Equivalent sound level ($L_{Aeq,45sec}$) in 1/3-octave bands** *in free field for 45-second master scaling sounds and road traffic sounds, expressed in dB(A).*

5. The test location

5.1. Reproduction of the indoor sound field

Playback methodology

The sounds were played back on a regular PC equiped with a Creative Sound Blaster Audigy Platinum Ex PCI card, by the use of Matlab or Sony SoundForge. The sound signal was then equalized by an Allen & Heath 12-channel mixer and 31-channel equalizer. Subsequently, the sound signal was amplified by a Bose 802II amplifier and sent to 4 Bose loudspeakers, which were placed stacked per 2 on 2 tripod stands, at a height of about 1.5 m. To be able to reproduce sound at frequencies below 50 Hz accurately, a HK SL218A powered subwoofer was also used. All loudspeakers were placed outside the house, in front of the main window. The 2 loudspeaker tripods were separated about 10 m from each other, and placed about 3 m from the façade. The subwoofer was placed in front of the window in between both tripods, at about 0.5 m from the façade. Figure 15 shows a sketch of the test house together with the loudspeakers.

The façade level was measured continuously during all experiment sessions using a B&K Investigator 2260 with a B&K 4189 0V free field microphone, which was placed at a distance of 5 cm from the window and at a height of 75 cm. The Investigator was also used to calibrate the playback system. Therefore pink noise was played back, which should give a façade level of 91.0 dB with a flat 1/3-octave band spectrum. Using the equalizer, a flat (± 3 dB for all 1/3-octave bands) spectrum could be acomplished ranging from 30 Hz to 16 kHz.

Reproducibility experiment

Preparatory to the listening experiments, and before the test house was hired, a reproducibility experiment was carried out in a house in Drongen, near Ghent (Belgium). This house is located close to a railway with traditional IR trains; Figure 12 shows the setup of the experiment. The procedure consisted of two phases. Firstly, during the passage of a train, the sound was recorded outdoor by 2 microphones separated 20 m from each other; for calibration the level was also recorded by a B&K Investigator 2260 sound level meter at the façade. At the same time, the binaural recording A was made inside the house. Secondly, the recorded sound was played back by 2 Bose loudspeakers in front of the house, separated about 10 m from each other. The volume was adjusted to reproduce the 1/3-octave band spectrum at the façade as accurately as possible. Simultaneously, the binaural recording B was made inside the house. For both binaural recordings, the window was closed.

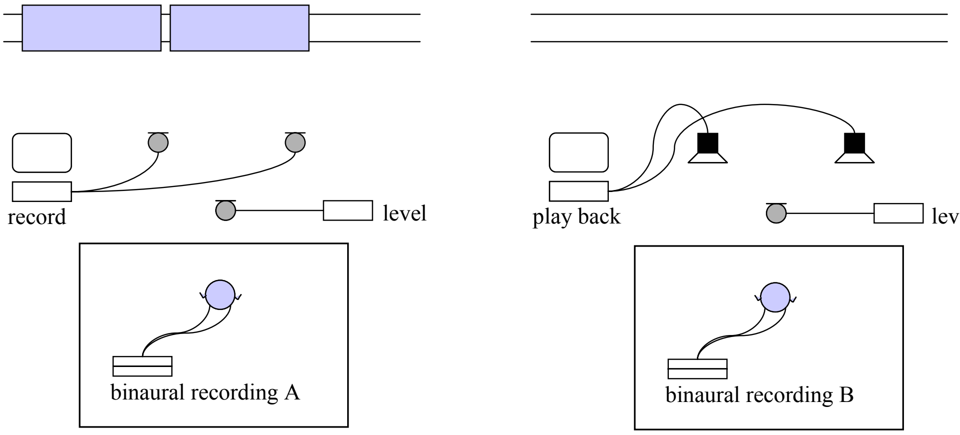


Figure 12. Setup of the reproducibility experiment in Drongen, Ghent.

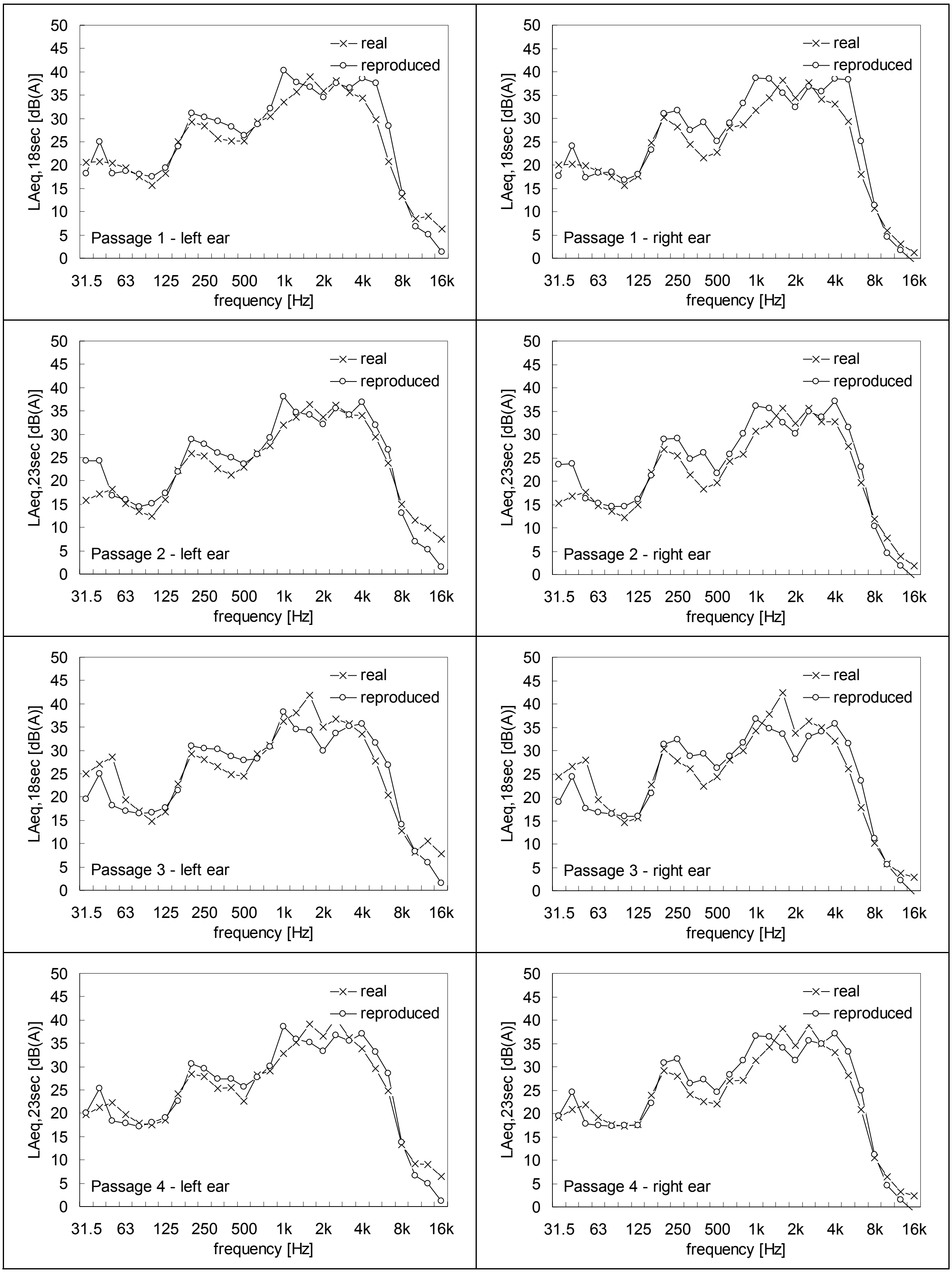


Figure 13. Real and reproduced binaural L_{Aeq} spectra of 4 train passages at the reproducibility test house.

During this preparatory test, we did not have a subwoofer or equalizer at our disposal. It should be mentioned that, while during the sample collection, the binaural head was used mainly as a fallback option, for this reproducibility experiment the binaural head recording is crucial. Ideally binaural recording A (real train) and B (reproduced train) should be equal. Figure 13 shows the binaural L_{Aeq} spectra of 4 different train passages. As one can see, the spectra correspond in most tertsbands within an error of about 5 dB. As the error spectrum is about the same for all train passages, using the equalizer this could be corrected. To be able to reproduce the low frequency part of the high speed trains accurately, it was also decided to use the additional subwoofer, as already mentioned. From these test it could be concluded that the reproduction strategy is very good for short distances and conventional trains. We see no obvious reason why this conclusion should not hold for high speed trains and Maglev systems.

5.2. Context characteristics of the test house in Westkapelle

In the search for a suitable experiment location, some factors had to be accounted for. It was decided to search for a test house in Zeeland, at north of the tunnel beneath the Western Scheldt, because only Dutch subjects were allowed for the listening tests, and the house should be reachable from Ghent within reasonable time. Only vacation houses could be adressed, because we wanted to hire the house only for a few weeks. Finally we found a test house at Joossesweg 86 in Westkapelle. Figure 14 shows some pictures of the house. Figure 14 (b) shows the living room with the window in front of which the speaker system was placed. The small window at the right can be opened. The pros of this house were:

1. The location. As the house is located near the end of an island between the 2 arms of the Scheldt, there are no large traffic axes. It is also located at the end of a dead-end street. This both results in a relatively low man-made background noise at the house.

2. The garden has a reasonable size, large enough to put the loudspeakers. The neighbours are at least some distance away. As it is located in a holiday park, it was expected that not much people would be there during the winter period.

3. Good places to recruit test persons (Zoutelande, Middelburg, Vlissingen) are located at only a few kilometers distance.

4. The visual setting is correct. At approximately 5 m from the window there is some greenery almost obscuring the view, so it is easy to imagine that a train passes by behind this.

5. The way people can enter the house makes that the subjects do not have to pass past any equipment. All equipment can be placed in a bedroom, that can be transformed to the control room.

6. The acoustic insulation of the house is normal; also is the reverberation time.

7. The house was not too expensive.

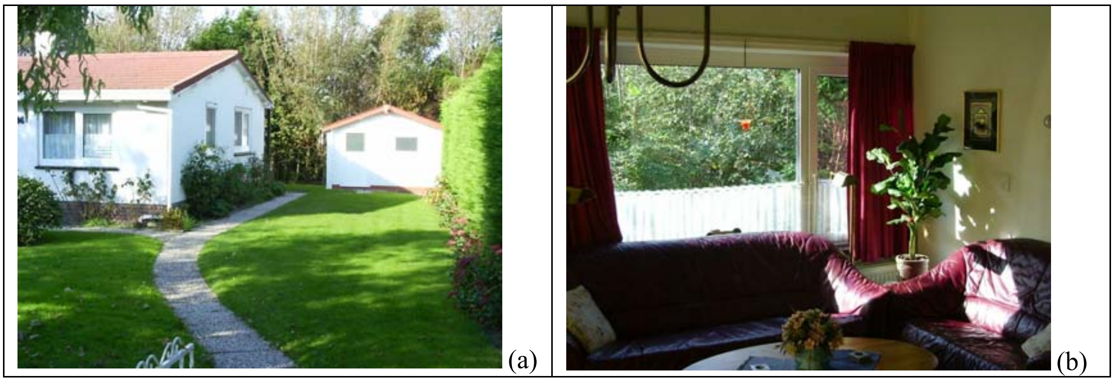


Figure 14. Some pictures of the test house in Westkapelle.

Unfortunately, there were also some negative aspects:

1. The house is very small. The living room is only 20 m^2, while the average Dutch living room is about 35 m^2. It is impossible to have all people facing the same window or wall, while they are sitting.

2. The electricity circuit is relatively old, there are only two 6A circuits. This makes that extra care should be taken on the power use of the equipment.

3. The living room has 2 windows on 90° walls, which could be a bottleneck to make a good 3D representation of the sound possible. On the other hand, there is a screen outside, reducing the sound noise level coming from around the corner.

4. Weather may be a problem; the house is located close to the sea. However, one cannot hear the waves breaking as there are some dunes in between. Autumn storms could be important for wind.

Despite of these disadvantages, we decided to take this house. As it turned out, none of the negative aspects caused problems.

Figure 15 shows a schematic drawing of the experiment house, together with a sketch of the positions of the loudspeakers and the façade sound level meter. The 7 possible sitting positions of the subjects are shown, as well as the position of the binaural head for all experiment sessions.

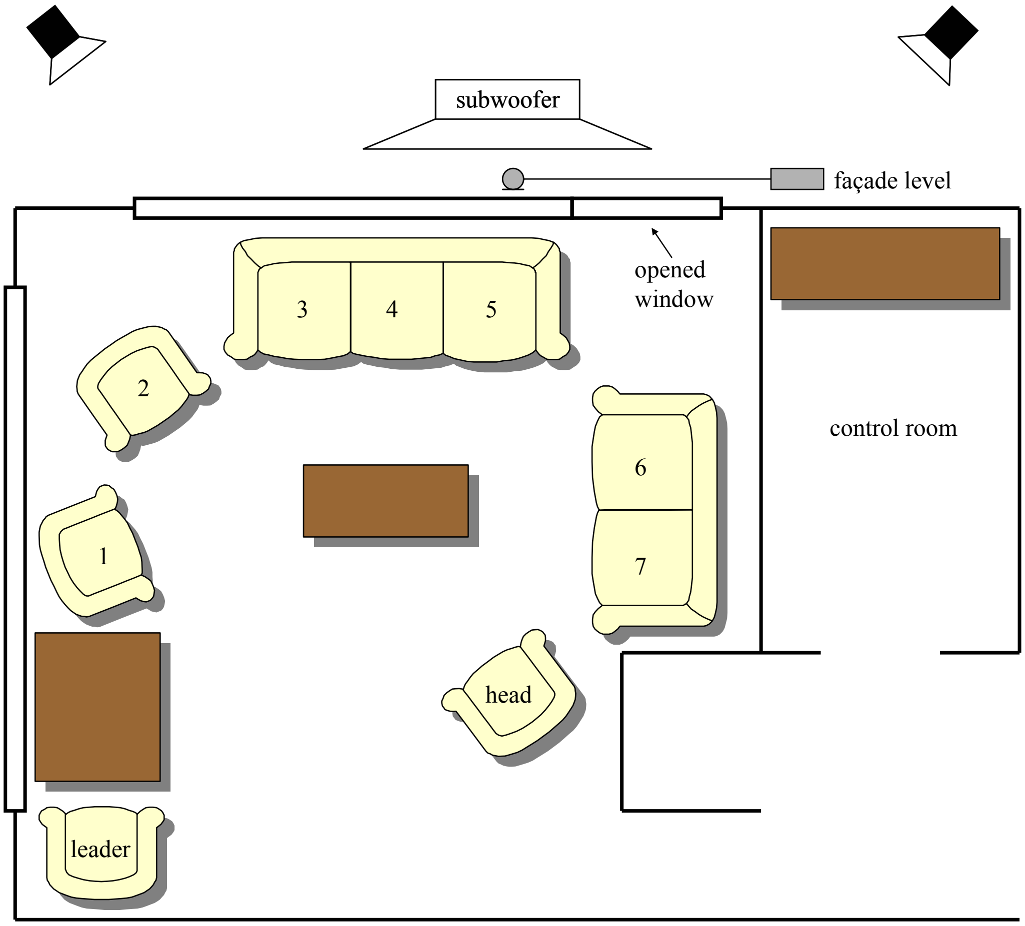


Figure 15. Schematic drawing of the experiment house (not to scale).

5.3. Acoustic characteristics of the test house in Westkapelle

Acoustic insulation, window open

The acoustic insulation of the test house can be extracted from the difference between the level measured at the façade and the recorded level inside the house by the binaural head. Figure 16 shows the spectral reduction of the sound from outdoor to the ear inside the house, using an average of the difference between the façade level and inside level for the loudest master scaling sound at various experiment sessions. Hereby, part of the window (about 60cm × 1m) as shown in Figure 15 was opened about 5 cm, which was also done for all listening tests.

Background noise levels

Table 11 gives some statistical levels and meteorological data. The levels inside the house were calculated from the first 2 hours of binaural recordings made during all listening experiments. The L_{A95} value can be used as an estimate of the acoustic background level inside the test house, as this value is almost independent of the man-made noise inside the house. One can see that for most experiment sessions, this value is below 30 dB(A). The levels at the façade were taken for the whole duration of each experiment session, which is approx. 4 to 5 hours. Meteorological data for all experiment sessions was obtained from the website of the Royal Netherlands Meteorological Institute, for the station of Vlissingen. The windspeed and temperature values are both daily means.

Figure 17 shows the relation between the background façade level and the windspeed. As can be expected from literature (Boersma et al., 1996), there is a good logarithmic correlation, which indicates that the background level at the house is mainly produced by the wind.

Table 11. Statistical background levels and meteorological data for all experiment sessions.

	Inside the house		**At the façade**		**Meteorological data**	
Session	**L_{A50} [dB(A)]**	**L_{A95} [dB(A)]**	**L_{A50} [dB(A)]**	**L_{A95} [dB(A)]**	**Windspeed [m/s]**	**Temperature [°C]**
16/11/2004 – 14u	46.6	28.1	49.2	46.3	6.2	10.6
17/11/2004 – 08u	44.1	31.1	51.5	48.8	11.9	11.5
18/11/2004 – 14u	46.7	29.1	49.7	45.1	7.3	8.6
19/11/2004 – 18u	42.4	29.4	69.2	48.8	8.5	6.3
20/11/2004 – 08u	47.5	29.3	47.9	45.5	5.3	5.0
22/11/2004 – 18u	44.9	28.5	50.6	49.0	10.8	10.9
28/11/2004 – 14u	38.8	25.0	46.1	43.3	4.8	8.4
3/12/2004 – 14u	40.9	27.0	42.5	39.9	2.5	5.8
4/12/2004 – 08u	50.8	30.1	44.6	41.7	4.3	4.7
7/12/2004 – 08u	36.8	26.6	44.5	41.2	3.0	5.6
7/12/2004 – 18u	45.1	29.8	41.8	39.8	3.0	5.6
8/12/2004 – 08u	44.9	29.5	40.9	39.0	2.5	6.6
8/12/2004 – 18u	38.2	27.3	45.4	40.0	2.5	6.6
9/12/2004 – 08u	41.1	25.1	41.2	39.0	3.9	2.1
9/12/2004 – 15u	46.1	28.4	44.4	40.5	3.9	2.1
10/12/2004 – 18u	43.1	28.3	46.6	42.0	4.6	2.9

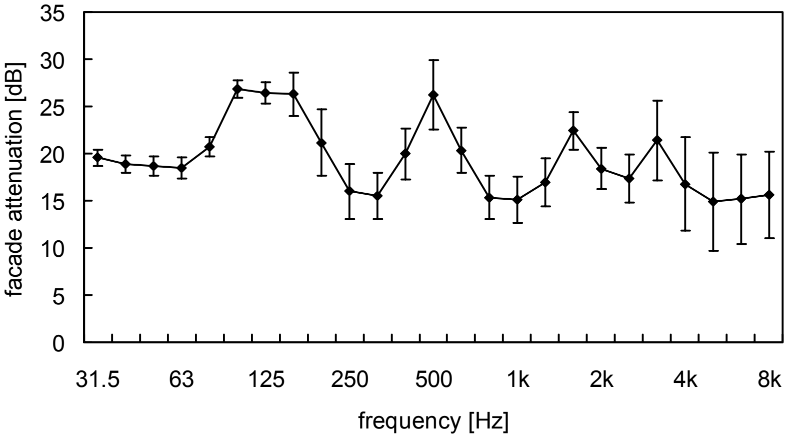


Figure 16. Difference between sound pressure level at the façade and sound pressure level at the ear of the indoor artificial head; error bars indicate the spread between experimental days.

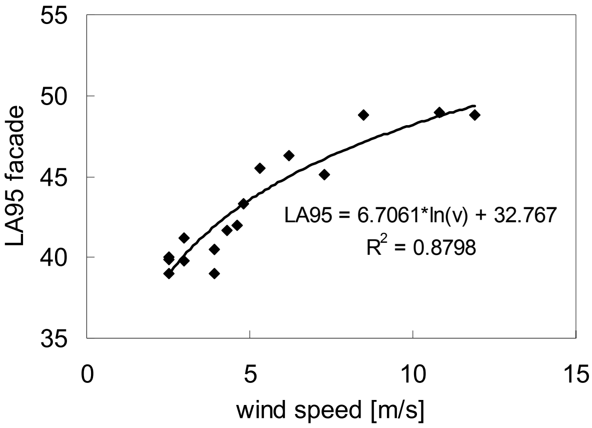


Figure 17. Relation between the L_{A95} level at the façade and the wind speed, during all experiment sessions.

6. The listening experiment

6.1. Underlying ideas

The panelists in the field listening experiment should be able to scale quantities of perceived noise annoyance in a comparable way within and between menus, containing noise from two or four train passages at different distances to the track as well as at different speeds (see Table 4). A menu had to be at least 10 min in order to contain four train passages at realistically scheduled intevals. Since 48 unique combinations of number of train passages, speeds and distances were to be scaled, experimental time would be too long for any one particpant to scale them all (480 min = 8h without pauses). Thus, the scaling task had to be shared among the 80 participants. Comparability between different participants' perceived annoyance scales was assured in the experimental design in several ways:

a. by letting clusters of panelists participate in simultaneous sessions of the field listening experiment;

b. by letting every panelist scale seven reference sound levels of road traffic noise (six repetitions) which allows for master scaling of perceived noise annoyance (i.e., between-subject calibration of perceptual scales, see Berglund, 1991);

c. by introducing one road-traffic noise menu which allows for relative comparison of noise annoyance between sets of menus (i.e., controlling for within-subject drift in use of numbers).

The noises from the three types of train passages (Maglev, TGV and IC) should represent natural speeds at the same four distances to the track (20, 50, 100 and 300 m). In this way, comparability between various acoustic measures of propagated noise from train passages was assured, as well as correpondingly for perceived noise annoyance and perceived auditory distance between listener and the track.

6.2. Experimental design

The field listening experiment consisted of three main parts, two training sessions, two sessions with 10-min menus (Experiment 1) and one session with all train noises of the menus, all road traffic noises of the training session (Experiment 2) as well as four road traffic noises. The overall structure and time schedule of the field listening experiment was the same for all of the 80 panelists (see graphical representation of layout of main field experiment in Figure 18):

1. 14-min Training Session 1 (2 x 7 sound levels of 45-min road traffic noise);
2. 70-min Experiment 1, part 1 (7 menus of 10 min);
3. 14-min Training Session 2 (same as Training Session 1);
4. 70-min Experiment 1, part 2 (7 other menus of 10 min);
5. 42-min Experiment 2 (all 42 different 45-min transport noise stimuli)
6. Filling in a brief version of the questionnaire used for recruiting panelists.

The 80 panelists were recruited and randomly assigned to participate in one of 16 sessions of Experiment 1; unique random orders of noise presentations in the other three experimental sessions (Training Session 1 and 2 and Experiment 2) were randomly associated with the 16 sessions of Experiment 1. The sub-groups of panelists were planned to be 5 but due to various circumstances at least 4 and at most 7 panelists took part in the 16 sessions. Reasons were no show or cancelled appointments which had to be compensated.

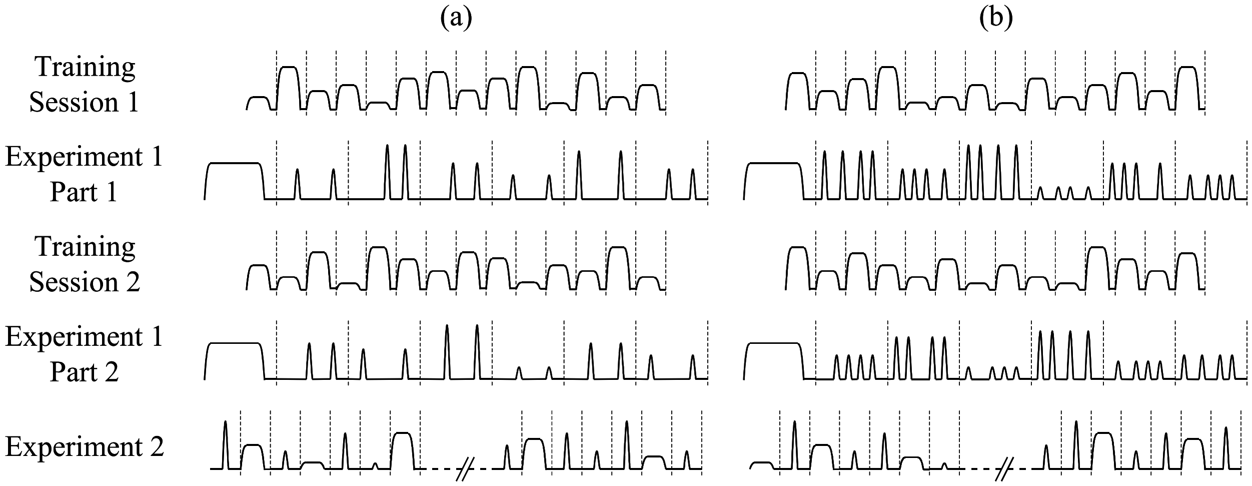


Figure 18. Graphical representation of the layout of the experiment, illustrated for two sub-groups of panelists, notated (a) and (b).

Training Session 1 and 2. In each of these two sessions, seven sound levels of the reference road traffic noise were scaled twice by each participant. Random presentation orders were used consisting of a first and second set of the seven sound levels; unique random orders for half of the sub-groups of panelists and the reverse orders for the other half. The LAeq,45s (in dB) and Zwicker loudness (in sone) of the reference sounds are found in Table 10.

Experiment 1. Since 48 unique combinations of train passages, speeds and distances were to be scaled, four unique sets of menus were created, two with Maglev train passages (two or four passages) and two with TGV and IC (two or four passages). Out of the 7 menus, in all sessions (both part 1 and 2) the first menu consisted of 10-min road traffic noise (label RT, 65.3 dB LAeq,10min), created by repeating one of the 45-min road traffic noises (label R2, 67.1 dB LAeq,45s). The following six 10-min menus all contained the same number of train passages (two or four), but various sets of train noises with regard to type, speed and distance. Four different kinds of 7-menu sessions were created for Experiment 1 and labeled A, B, C and D. In these kinds of sessions, Menu 2-7 contained either Maglev noise passages or IC and TGV train passages. A session either contained two or four passages (A and B or C and D, respectively), and the same sub-group of panelists either always assessed two train passages (in part 1 and part 2 of Experiment 1) or always four train passages. Two sub-groups of 4 to 7 panelists participated in each kind of session (A1, A2, B1….D2 in Table 12) and different random orders were used in presenting the train passages in Menu 2-7 in both part 1 and part 2. More details on the design of Experiment 1 is given in Table 12. As is also seen in this table, immediately after Menu 2-7, the panelists were to report on the overall train noise annoyance with reference to what they had heard after the road traffic noise (1h exposure of 12 or 24 train passages). Table 4 shows the dB values for train passages and menus in ASEL, LAeq,45s and LAeq,10min, footnote inclusive. Table 8 shows the LAeq,10min value for the road-traffic menu.

Table 12. Overview of experimental design of Experiment 1 of the main field experiment.

Kind of session	**Part 1**		**1-h train reports**	**Part 2**		**1-h train reports**	**Number of panalists**
	Menu 1	**Menu 2-7**		**Menu 1**	**Menu 2-7**		
A1	Road traffic RT	2 passages of 6 Maglev (3 speeds x 2 distances)	-	Road traffic RT	2 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=10	N=10
A2	Road traffic RT	2 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	-	Road traffic RT	2 passages of 6 Maglev (3 speeds x 2 distances)	N=10	N=10
B1	Road traffic RT	2 passages of 6 Maglev (3 speeds x 2 distances)	N=5	Road traffic RT	2 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=10	N=10
B2	Road traffic RT	2 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=4	Road traffic RT	2 passages of 6 Maglev (3 speeds x 2 distances)	N=9	N=9
C1	Road traffic RT	4 passages of 6 Maglev (3 speeds x 2 distances)	N=9	Road traffic RT	4 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=9	N=9
C2	Road traffic RT	4 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances	N=10	Road traffic RT	4 passages of 6 Maglev (3 speeds x 2 distances)	N=10	N=10
D1	Road traffic RT	4 passages of 6 Maglev (3 speeds x 2 distances)	N=10	Road traffic RT	4 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=10	N=10
D2	Road traffic RT	4 passages of 2 IC (1 speed x 2 distances) and 4 TGV (2 speeds x 2 distances)	N=12	Road traffic RT	4 passages of 6 Maglev (3 speeds x 2 distances)	N=12	N=12

Footnote. The 1-h reports on annoyance are unfortunately lacking from the two A1 and A2 sessions. In Experiment 1 of the extra field experiment, the Maglev train part was replaced by menus containing local road traffic at low, medium and high intensity, each at 25 and 100 m distance to road (see Tables 8 and 9).

Experiment 2. In this last experiment, each of the 8 groups of panelists listed in (A1, A2, B1, …..D2) judged perceived noise annoyance and auditory distance to track/road of unique random orders of 42 45-second transport sounds. In these random orders, each of the 7 sound levels of the reference road traffic (L1-L7 in Table 10) appeared twice; all other transport sounds appeared once. These latter sounds were: one train passage of Maglev at 3 speeds times 4 distances, one train passage of TGV at 2 speeds and 4 distances, one train passage of IC at one speed and 4 distances, and free flow traffic at four distances to a highway. The dB-values in LAeq,45s of all these 24 train passages and 4 road traffic noises are found in Table 4 and Table 6, respectively. The inter-stimulus interval for responding was set to 15 sec. The panelists' task was to scale first the perceived noise annoyance of a transport noise stimulus and thereafter directly scale the auditory distance.

Closure with Brief Version of Recruiting Questionnaire. The last task of the 80 panelists were to fill in a brief version of the recruiting questionnaire. The purpose was to use their responses for a reliability check on the questions considered to be most central in the selection procedure, as well as to see if there appeared any drift in their reported personal characteristics. The repeated questions were questions number 20 to 26 and question number 29 from the recruitement questionnaire (Appendix B).

An extra field listening experiment

Apart from the main listening field experiment described in detail above, an extra field experiment was conducted with 21 panelists. The overall design of this extra field listening experiment was exactly the same, but for the menus of Experiment 1, part 1 ***or*** part 2 and Experiment 2. The focus of the extra field listening experiment was to obtain annoyance values comparative to train noise passages also for six levels of low, medium and high intensity local road traffic; each intensity at 25 or 100 m to road (see Table 8 and Table 9). The panelists participated in **subgroups of 5 to 6 persons**.

In Experiment 1, the set of 7 different 10 min menus of either part 1 ***or*** part 2 included the six levels of local road traffic in **random order** subsequent to the identical first road traffic 10-min menu which was used in the main field experiment focussing on train passages in all menus. The other part 1 ***or*** part 2 consisted of the menus of IC and TGV passages at 25 and 100 m. In Experiment 2 in the extra field experiment, the 45 sec excerpts of the six local road stimuli replaced the Maglev sounds recorded at 50 and at 200 m amongst the stimuli of Experiment 2 of the main field experiment**.** The total number of sounds to evaluate thus remained 42.

6.3. Scaling methods used in the field listening experiment

Scaling perceived noise annoyance with reference sounds

During the field listening experiments, perceived noise annoyance of the transport noises was scaled with the method of free-number magnitude estimation (e.g., Marks & Algom, 1998). In the different parts of the experiment, the same set of seven reference sound levels of road traffic noise were introduced as common experimental context to be utilized also for controlling for individual panelists' choice-of-numbers when scaling different sets of transport noises. Since at most two panelist groups each (n=4-7) scaled all the same transport noises throughout the field listening experiment (Table 12), the plan was to use the reference sound levels of road traffic noise (L1-L7) for master scaling perceived noise annoyance (e.g., Berglund, 1991). As an extra control, the 7 10-min menus in Experiment 1 were always started with the identical 10-min road-traffic noise menu (Menu 1 created from the 45-sec road traffic R2, which in turn is identical to the 45-sec reference sound L5). This type of contextual control of individual differences in scaling behavior is needed in any study involving self-reports from participants, whether questionnaire surveys or experimental studies. In both the main and the extra field experiment, the same invariant sound-level range of references was used in Training session1 for Experiment 1, part 1, Training session 2 for Experiment 1, part 2 and inside Experiment 2. The master scaling was thus grounded in annoyance evaluations of the reference sound levels of road traffic noise and thus helped to define the scaling context as well as was used for calibrating individual annoyance scales to a common master scale of annoyance (e.g., Berglund, 1991).

Noise annoyance scaling questions and response sheets

After being welcomed and seated in the living room (Figure 14), sub-groups of 4 to 7 panelists were at first given an overview of the various parts of the field experiment. They were instructed to be seated during the various experimental parts, which each had its own specific instruction of what they were to do. In the first experiment (Experiment 1), they were to be seated, to relax and to read newspapers and magazines that were provided. [Own reading material of other kind was not allowed.] For longer periods of time delimited by the experimenter, the panelists were to report on how annoying they had found the transport noise to be while they had been relaxing and reading. The panelists started with a training session in which they were to listen to various road-traffic sounds and learn the magnitude estimation method by which they were to report noise annoyance during the subsequent experiments. The experimenter served refreshments (juice, coffee, tea) during pauses. In Experiment 1 (as well as Experiment 2 and training sessions), the panelists were reminded of their noise annoyance tasks by a written version of the specific question on each response sheet (see below).

Variously colored response sheets in various format were used, all with the scaling question in writing and a response box beneath. The panelist filled in their own answer (number) themselves. A detailed instruction for how to conduct free-number magnitude estimation was given in the beginning of the two training sessions both orally and in written form (see Appendix C). It should be noted that zero responses do not mean that panelists could not hear the noise but rather that they did not consider the noise to be annoying.

Training sessions. The scaling of noise annoyance with free-number magnitude estimation was accomplished by the following question in Dutch in the two training sessions (1 and 2*):"In welke mate zou u gehinderd worden door dit verkeersgeluid indien u het tijdens het relaxen hoorde?"* The duration of the 14 road traffic noise presentations were each 45 sec with a 15-sec interval. The scale value was written down on A6-response sheets in a 14-page stapled booklet; all colored beige for Training session 1 and colored gray for Training session 2. In this way, the answers to the preceeding series of reference sound levels could not easily be remembered and a more intuitive strategy was hopefully used by the panelists. Before starting each training session, the panelists could listen to a few examples of the reference sounds to appear in the session. The experimenter kept an eye on correct response sheets by page number.

Experiment 1. The scaling of noise annoyance with free-number magnitude estimation was accomplished by the following question in Dutch in the two parts of Experiment 1*: "In welke mate werd u gehinderd door verkeersgeluid gedurende deze periode?"* The panelists were informed that they now were to use the same scaling procedure as in the training session but now assess the traffic sounds during longer periods of time. Since the training session only contained road traffic noise, they were also informed that there would be train noise in the menus. A set of eight non-stapled A5-response sheets in the same unique order of colors lay on a table before each panelist. The colored sheet lay there during the 10-min menu and right before it ended, the experimenter asked the panelists to write down their assessments. Thereafter, the experimenter collected the sheets, which were marked on the back with the panelists identification number and menu number (1-7). The same colored sheet would thus lay before all panelists at the start of the next 10-min menu. After the 7 menus of transport noise, a white sheet was left. The panelists were now asked for an overall retroactive noise annoyance assessment of the 6 last train-noise menus (last 60 min), see Table 12. The question on this sheet read in Dutch: *"Denk nu terug aan het voorbije uur. Dit wil zeggen, de periode sinds u voor het laastst het geluid van de autoweg hoorde. In welke mate werd u globaal, over dit voorbije uur, gehinderd door verkeersgeluid?".*

Experiment 2. The scaling of noise annoyance with free-number magnitude estimation was accomplished by the identical question in Dutch as used in the two training sessions*: "In welke mate zou u gehinderd worden door dit verkeersgeluid indien u het tijdens het relaxen hoorde?"* The duration (45 sec) and spacing (15 sec) of the 42 noise presentations were also the same. The scale value was written down on A6 response sheets in two 21-page stapled booklets. Each sheet has a new color; all first session booklet started with red and the second session booklet with orange. The experimenter kept track of panelists correct response sheet by color (and its page number). After each noise annoyance report in the booklet, the auditory distance was also assessed and reported on a large green A-4 sheet (see next paragraph) at the side of the booklet.

Scaling auditory distance in meter

In Experiment 2, auditory distance of trains from track (one passage only) and free flow road traffic from major road (references inclusive), was scaled directly in meter by the panelists. The exact question in Dutch was*: "Gelieve de afstand in te schatten tussen de bron van het verkeersgeluid en deze woning?*", then a response line and "meter". Large green A-4 response sheets were used in which the question was written at the top, and the number of the noise presentation was listed in two rows, 21 numbers in each of two columns (one column for each of two sessions). This direct method of scaling in meter was chosen in order not to confuse these assessments with the noise annoyance magnitude estimates. It is also the same method as earlier used by, for example, Preis and Golobiewski (2004) for moving noise sources such as train passages.

6.4. Master scaling

During the field listening experiments, perceived noise annoyance was scaled with the method of free-number magnitude estimation, utilizing the same set of seven reference sound levels of road-traffic noise to be able to control for individual panelists' choice-of-number behavior in scaling target train and road-traffic sounds. Apart from scaling targets in the same context as the references, master scaling also involves a transformation of individual panelists' annoyance scales to a common "calibrated", so called master scale. This master scale of annoyance is defined by the psychoacoustical master function of annoyance for the reference road traffic noise. Typically, the group reference function is chosen. In applying master scaling, it is here hypothesized that true interindividual variability in annoyance would remain whereas interindividual variability due to choice of number behavior would disappear. In the present field experiment, such potential true variability in annoyance may for example be caused by panelists' noise sensitivity.

Master scale transformations

The master scale transformation is as follows for the simple version of psychophysical power function which usually fits loudness or annoyance data for complex sounds (see Berglund, 1991; Berglund & Preis, 1997). That is

$$R = c\ S^n \qquad (1)$$

where R stands for annoyance, S for sound intensity (linear scale), c is a multiplicative constant, and n is the exponent (e.g., Stevens, 1956, 1975). Let this equation for the Master Function of the references be subscribed by *m* and the corresponding reference equation for each panelist be subscribed by *i*, equate the stimulus intensity (S_i=S_m) and rearrange the terms. The resulting formula for the Master Scale Transformation is

$$R_m = c_m\ (R_i/c_i\ )^{n_m/n_i} \qquad (2)$$

where R_i is the empirical annoyance of the reference and R_m is this annoyance transformed to the Master Scale. By inserting the individual empirical annoyance values of the target stimuli (R_i) into Equation 2, these can be transformed to the unit and reference points of the Master Scale of perceived intensity (R_m), defined for the set of *annoyance of the references*.

Since the annoyance scaling in the present field experiments was conducted with a background noise present in the experimental room, another version of the psychophysical power function, which includes a constant for the extrapolated annoyance threshold (S_0) may be used,

$$R = c\ (S- S_0)^n \qquad (3)$$

Using the same subscripts, *i* and *m*, for individual annoyance (R_i) and annoyance of the master scale (R_m), equate the stimulus intensity (S_i=S_m), and rearrange the terms, result in the following equation for the master scale transformation

$$R_m = c_m\ [(S_{0m} - S_{0i}) + (R_i\ /\ c_i)^{\ 1/\ n_i}]^{\ n_m} \qquad (4)$$

Please note that the master scale transformation in Equations 2 and 4, only includes constants derived from psychophysical power functions for the set of references. Thus, the two extrapolated thresholds (S_{0m} and S_{0i}) originating from Equation 3 (S_0) also refer to the annoyance function of the reference road traffic noise.

The influence of background noise annoyance in our field experimental room may, alternatively, be taken care of by a logarithmic function. Using the same type of notation,

$$R = a + b \log S \qquad (5)$$

where a is a multiplicative consant and b is the slope of a logarithmic function (lin-log plot). Using the same subscripts, *i* and *m*, for individual annoyance (R_i) and annoyance of the master scale (R_m), equate the stimulus intensity ($\log S_i$=$\log S_m$), and rearrange the terms, result in the following equation for the master scale transformation.

$$R_m = [(b_{m/}\ b_i)\ (R_i - a_i)] - a_m \qquad (6)$$

To facilitate comparability in goodness of fit between the two power functions (Eq. 1 & 3) and the logarithmic function (Eq. 5), it is helpful to display stimulus intensity in a ("common") logarithmic scale. For the three functions, it is favorable also to evalute the fit in terms of a rectilinear function. By taking the logarithm of Equation 1 and 3, we obtain Equation 7 and 9, respectively:

$$\log R = \log c + n \log S \qquad (7)$$

and

$$\log R = \log c + n \log (S - S_0) \qquad (8)$$

The two power fuctions are rectilinear in log-log coordinates with log c as intercept (based on the multiplicative constant c in lin-lin plots) and n as slope; for simplicity these constants are in the overview given in Table 16 notated "a" and "b", respectively.

Master scaled annoyance (R_m) of the target noises (Maglev, TGV, IC and road traffic noise R1-R4) can also be expressed in Perceived Noise Equivalents (PNE) of the reference. Panelists' annoyance expressed in individual dB-values in PNE of the reference may alternatively be “master scaled” by a transform to a commonly agreed upon “annoyance master function of the references”. (See Figure 21 for illustration)

7. Data quality analyses on reference sounds

The panelists individual ability to make magnitude estimations of perceived noise annoyance was evaluated for the reference road-traffic noise. In total, perceived noise annoyance of seven sound levels of this reference noise was assessed six times during the listening experiment, twice in both Training Session 1 and 2 and twice in Experiment 2. This quality evalution of the panelists' annoyance scaling ability was made for this reference noise in two ways: (a) by scrutinizing each of the 80 panelists' test-retest reliability, and (b) by scrutinizing each of the 80 panelists' psychophysical functions for noise annoyance and sound level expressed in dB LAeq,45min. During this stage of the data treatment, all individual data sets were also controlled and cleaned by back-tracking for errors in the original response sheets, in the experimenters' notes, and in the sound recordings from experimental sessions. The raw magnitude estimtes and raw auditory distance data were cleaned according to the information given in Table 13.

Table 13. Errors in the original data set that were corrected after the quality control.

Participant	Experiment	Stimulus
150	1	Assessments nos. 4-14 in the original data set should refer to presentation nos. 3-13, leaving a missing response for presentation no.14 (not at presentation no. 3, as in the original data set)
84	2	Assessment no. 20 (L07) excluded: outlier
1, 6, 23, 37, 38	2	The participants did not notice presentation no. 12 (M10), because of a mobile phone signal during experiment. Assessments no. 12-20 in the original data set should therefore refer to presentation nos. 13-21, leaving a missing response for presentation 12 (M10). The zeros for presentation no 21 in the original data set should be excluded.

7.1. Test-retest reliability

Main Field Experiment

The test-retest raliability of the annoyance scales of the 80 panelists in the main field experiment was found to be very good. Pearson's coefficient of correlation was calculated for the six noise annoyance scales produced by every panelist for the seven sound levels of the reference road traffic noise, Table 14. The test-retest reliability was between 0.81 and 0.88 for within and between noise annoyance data sets of Training session 1, Training session 2 and Experiment 2. The standard error of these coefficients was low, between 0.014 and 0.019. The four data sets of the training sessions had an average test-retest reliability of 0.86 (±0.017SE); the two data sets of Experiment 2 had a somewhat lower average of 0.83 (±0.018SE).

Table 14. Main field experiment: Test-retest coefficients of correlation for perceived noise annoyance of the se ven sound levels of the reference road-traffic noise

Session/Experiment	**Set of seven references**	**Training Session 1**		**Training Session 2**		**Experiment 2**	
		Set 1	**Set 2**	**Set 3**	**Set 4**	**Rep. 1**	**Rep. 2**
Training Session 1	**Set 1**						
Training Session 1	**Set 2**	0.82 ±0.015					
Training Session 2	**Set 3**	0.86 ±0.014	0.87 ±0.016				
Training Session 2	**Set 4**	0.86 ±0.017	0.88 ±0.020	0.87 ±0.019			
Experiment 2	**Rep.1**	0.83 ±0.015	0.83 ±0.021	0.82 ±0.019	0.85 ±0.020		
Experiment 2	**Rep.2**	0.84 ±0.015	0.85 ±0.019	0.81 ±0.016	0.84 ±0.019	0.82 ±0.015	

Footnote. Each data cell contains an average Pearson's coefficient (r) and its standard error (±SE) for the 80 panelists. Arithmetic means were used for calculating average coefficients for the group of 80 panelists.

Extra Field Experiment

The test-retest reliability of the annoyance scales of the 21 panelists in the extra field experiment were found to be very good. Pearson's coefficient of correlation was calculated for the six noise annoyance scales produced by the 21 panelists for the seven sound levels of the reference road traffic noise, Table 15. Although based on fewer panelists, 21 as compared to 80, the test-retest reliability in this extra field experiment was between 0.76 and 0.87 for within and between noise annoyance data sets of Training session 1, Training session 2 and Experiment 2 (road traffic reference sounds only). Probably because of fewer panelists, the standard error was larger than in the main field experiment, between 0.018 and 0.078. The four data sets of the training session had an average test-retest reliability of 0.85 (±0.015SE), the two data sets of Experiment 2 had a somewhat lower average of 0.84 (0.030SE).

Table 15. Extra Field Experiment: Test-retest coefficients of correlation for perceived noise annoyance of the seven sound levels of the reference road-traffic noise.

Session/Experiment	**Set of seven references**	**Training Session 1**		**Training Session 2**		**Experiment 2**	
		Set 1	**Set 2**	**Set 3**	**Set 4**	**Rep. 1**	**Rep. 2**
Training Session 1	**Set 1**						
Training Session 1	**Set 2**	0.84 ±0.038					
Training Session 2	**Set 3**	0.84 ±0.036	0.82 ±0.048				
Training Session 2	**Set 4**	0.87 ±0.021	0.85 ±0.054	0.91 ±0.018			
Experiment 2	**Rep.1**	0.79 ±0.051	0.76 ±0.061	0.85 ±0.031	0.84 ±0.036		
Experiment 2	**Rep.2**	0.82 ±0.035	0.78 ±0.078	0.85 ±0.025	0.87 ±0.031	0.84 ±0.030	

Footnote. Each data cell contains an average Pearson's coefficient (r) and its standard error (±SE) for the 21 panelists. Arithmetic means were used for calculating averge coefficients for the group of 21 panelists.

7.2. Quality of the reference psychophysical functions

Psychophysical functions were fitted to each panelists' data sets of noise annoyance as a function of sound level of the reference road traffic noise (dB LAeq,45s); in total 101 panelists (80 panelists in the main field experiment and 21 panelists in the extra field experiment). Since annoyance was scaled, not loudness, it is possible that the transport noise was heard but not considered to be annoying. Thus, also zero reports are informative on annoyance. More background sound was present than is commonly allowed in laboratory experiments. These factors may affect the psychophysical function for the reference road traffic (as well as the target train and road-traffic noises) such that the function will be slightly curvilinear in double logarithmic coordinates (i.a., lower sound levels are partially masked by background noise). Visual inspection of individual panelists' psychophysical log-log plots (Eq. 7) indicated a slightly curvilinear trend in many panelists. For this reason, both the simple and complex psychophysical power functions (Eq. 1 & 3) and the logarithmic function (Eq. 5) were fitted and evaluated as potential road-traffic noise reference functions.

Table 16. Main and extra experiment: Distribution of constants of panelists' individual psychophysical functions for perceived noise annoyance as a function of sound level (LAeq,24sec) for the road traffic noise used as reference.

Type of Function Fitted *Listening Experiment*	**Number of panelists**	**Number of data sets**	**Constants of psychophysical function**		
			r^2	**a**	**b**
"Power function, Eq. 1"			Log R = a + b * LAeq,45s		
Main Experiment: Training session 1 and 2	80	4 sets of 7 stimuli (n=7)	0.93 ±0.051	-0.261 ±0.650	0.022 ±0.007
Extra Experiment: Training session 1 and 2	21	4 sets of 7 stimuli (n=7)	0.92 ±0.016	-0.224 ±0.133	0.024 ±0.002
Main Experiment: Experiment 2	80	2 sets of 7 stimuli (n=7)	0.85 ±0.012	-0.257 ±0.0.88	0.021 ±0.001
Extra Experiment: Experiment 2	21	2 sets of 7 stimuli (n=7)	0.83 ±0.027	-0.120 ±0.153	0.022 ±0.001
"Logarithmic function"			R = a + b * LAeq,45s		
Main Experiment: Training session 1 and 2	80	4 sets of 7 stimuli (n=7)	0.95 .±0.061	-67.27 ±61.26	1.450 ±1.230
Extra Experiment: Training session 1 and 2	21	4 sets of 7 stimuli (n=7)	0.92 .±0.018	-123.10 ±47.29	2.526 ±0.919
Main Experiment: Experiment 2	80	2 sets of 7 stimuli (n=7)	0.78 .±0.014	-49.13 ±5.22	1.130 ±0.109
Extra Experiment: Experiment 2	21	2 sets of 7 stimuli (n=7)	0.89 ±0.025	-97.36 ±40.02	2.211 ±0.923

Footnote. (1) Number of data sets refer to raw noise annoyance values, if n=7 for 4 or 2 sets, then an average of four or two, respectively, raw annoyance values was taken for each of the 7 reference sound levels. (2) Type of function fitted was either "power functions" in the form given (Eq. 7) or "lograthmic functions" (Eq. 5). In both cases, dB-values were entered for S; thus, the exponents of the power function (Eq. 1 in double linear coordinates) is found in the upper part of table column b, if cell value is multiplied by 10 for the case of sound intensity (or by 20 for the case of sound pressure). The constant b in the lower part of the table refers to the slope of the logarithmic functions (Eq. 5. lin-log coordinates).

In psychophysical experiments on complex sounds, power functions typically fits loudness data obtained with magnitude estimation well with exponents in the order of 0.20-0.25, as compared to loudness data for tones and white noise with exponents of 0.30 (Eq.1; e.g., Stevens, 1975; Berglund et al., 1976). In laboratory experiments where complex sounds mainly vary with regard to sound level, and not with type of noise (different spectra), psychophysical functions for annoyance will to a large extent be loudness-based. This ought to be the case also in the present Training sessions 1 and 2 including only the reference road traffic noise. The individual panelists' power functions for annoyance of the reference noise showed a normal distribution with an average of 0.22 or 0.21 (n=80) *and* 0.24 or 0.22 (n=21) in the (two) training sessions or Experiment 2, respectively, in the main *and* the extra experiments (Table 16). Also the multiplicative constants of the corresponding sets of power functions were of similar size and showed normal distributions. These results are in agreement with earlier knowledge on loudness and annoyance functions obtained in psychophysical laboratory experiments..

The average annoyance variance explained by sound level (LAeq,45sec) of the reference road traffic, was found to range from 83 to 93% (±1.2-5.1% SE) for the power function (Eq 1) and from 78 to 95% (±1.4-6.1% SE) for the logarithmic function (Table 16). Our small sets of individual annoyance data (only 7 reference sound levels), which obviously fitted well to the power function. Because of the low exponent (≈0.20 for sound intensity) the annoyance of the reference would also, as in the present case, be expected to fit well to a logarithic function. The more complex power function (Eq. 3) involving an "annoyance threshold" did not substantially improve the fit although three constants were used. However, three constants for fitting a funcion to seven empirical data points is a case of overfitting.

Since all the 101 panelists were able to produce acceptable individual power functions of annoyance as a function of sound level for the reference (Table 16), we decided not to exclude any panelist from further data treatment. All have proven that they are capable of conducting magnitude estimation, and all have produced acceptable annoyance data that may be allowed to be transformed to a common master scale of annoyance. This is a prerequisite for "calibrating" the individual annoyance scales for the target train and road traffic noises by the master scaling procedure. Since any type of function may be used for the master scale transformation we here chose to use the logarithmic function for annoyance. This choice was based on the following:

- The logarithmic function fitted the noise annoyance of the reference road traffic noise marginally better than the power function, probably because of the background noise present in the field experimental room.

- The power function is very sensitive to tranformation of annoyance outliers among the target train and road-traffic noises, resulting in extreme values. As a consequence arithmetic means of annoyance were not appropriate to calucluate unless the outliers were excluded.

- When the empirical reference sounds were transformed into master scale annoyance units, utilizing a power function or a logarithmic function, the power group transformed annoyance of the reference sounds produced a slightly negatively accelerating curvature in log-log plot whereas the annoyance transformed according to the logarithmic function were rectilinear in a lin-log plot.

- The complex power function with an "annoyance threshold" was exlcuded because of overfitting, although this approach would also have solved the curvature problem. The problem of tranforming annoyance outliers would however have remained (second point above).

- The master scaling according to the three candidate functions (Eq. 1, 3 & 5), will, in principle, not affect the interpretation of the main results, that is, the interrelations among the three types of trains and road traffic noise.

For the purpose of being able to compare the annoyance scales obtained by differrent panelists for different sets of train passages and road traffic, master scaling was conducted according to the logarithmic function. The master function was defined to have the average slope of the individual functions in Training session 1 and 2. The intercept of the master function was set to produce a value of zero for the two passeges of train sound labled M10 because a majority of the panelists (84%) reported its annoyance to be zero in Experiment 1. One rationale for basing the master scale of annnoyance in Experiment 1, instead of Experiment 2, was that the 10-min menus represented more realisic home exposure conditions than the 45-sec excerpt noise in Experiment 2. The same master function was selected and used for master scaling annoyance in the main and extra field experiments. It was thus based on Training session 1 and 2 and Experiment 1 of the main field experiment:

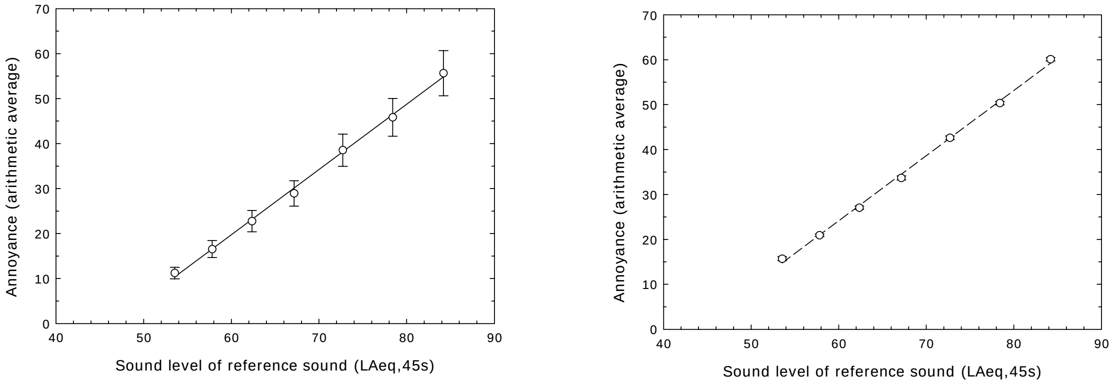
$$R = -62.91 + 1.45 \log S \qquad (9)$$

where log S is the road-traffic reference sound level in dB LAeq,45s.

Road-traffic reference psychophysical functions

Empirical logarithmic functions for annoyance of the road traffic noise reference are shown in the left hand diagrams of Figure 19 and Figure 20; arithmetic means and standard errors are displayed. From top to bottom, the functions refer to the two training sessions before Experiment 1 and to Experiment 2 of the main field experiment as well as correspondingly for the extra field experiment. In the corresponding right hand diagrams, the same empirical annoyance data for the road traffic reference sound levels are shown together with their own annoyance function after master scaling; again the arithmetic means and the very small standard errors are displayed. The lines fitted to the transformed annoyance data are identical to the master function (Eq. 9), Obviously, the variation in average annoyance with sound level remains, and the standard error which here represents interindividual variability is reduced to a minimum. Figure 19 and Figure 20 was produced in order to check that no mistake was made in the transformation constants of Equation 6, which will also be used for transforming the annoyance values of all the target train and road-traffic noises to be presented in the results section below.

Main experiment : training session



Main experiment 2

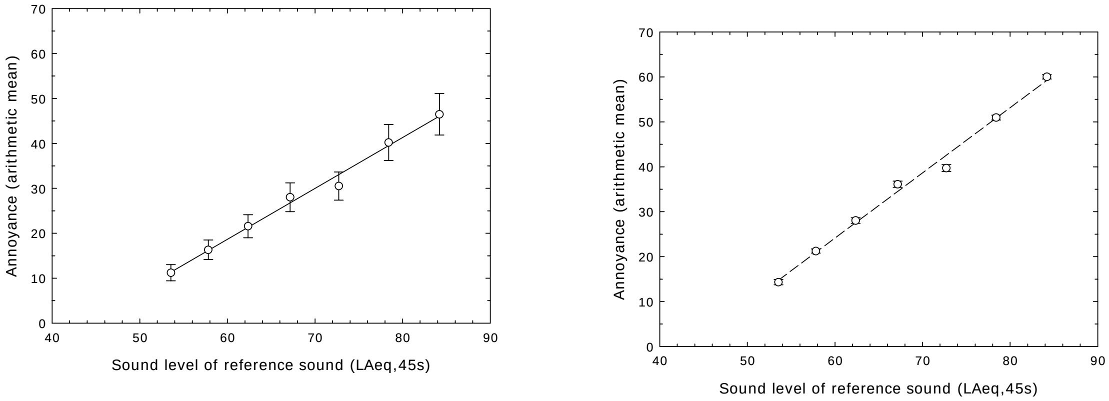
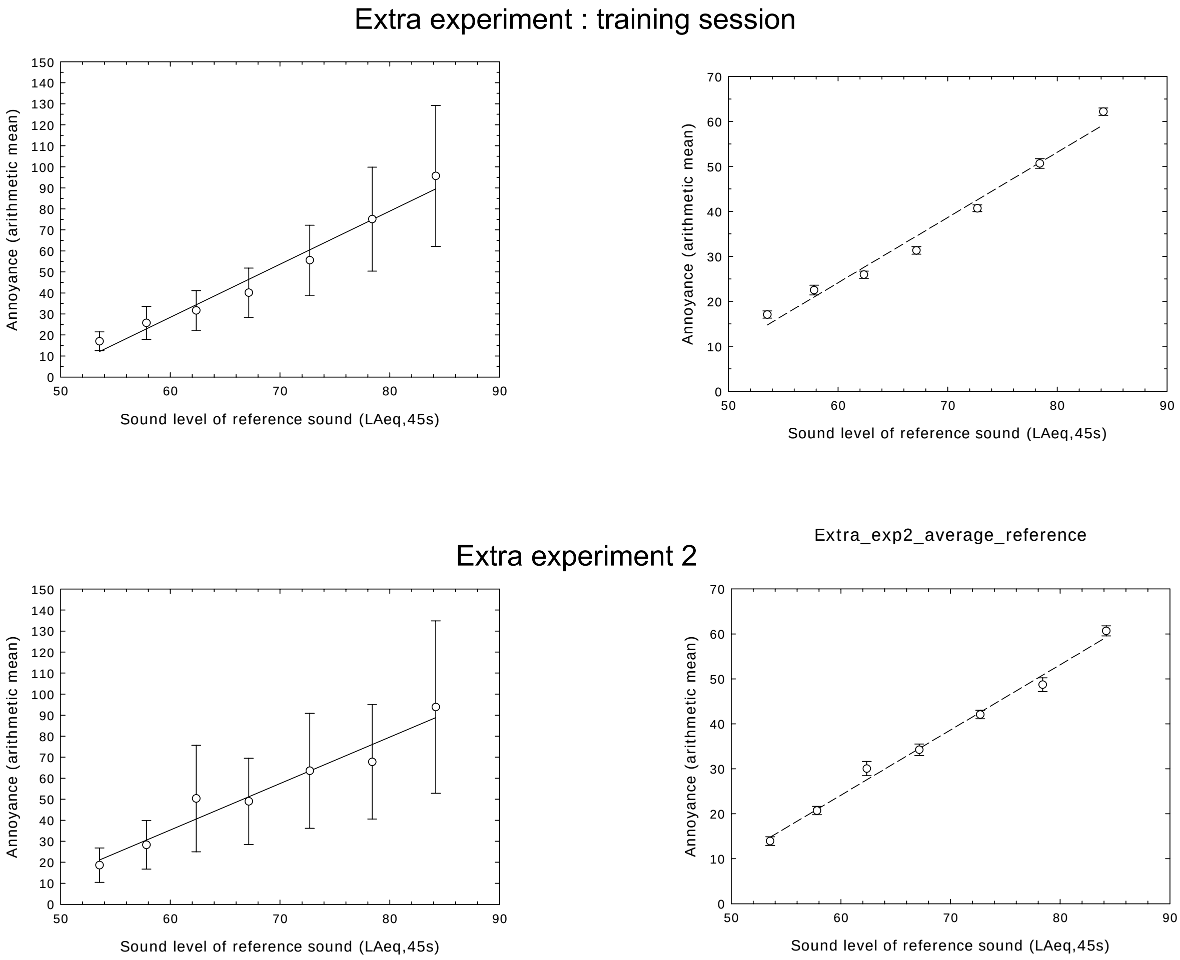


Figure 19. Main experiment. Psychophyscial functions for annoyance of the road traffic reference sounds shown before and after master scaling of annoyance in left and right set of diagrams, respectively (arithmetic means and standard error of empirical data).



Extra experiment : training session

Extra experiment 2

Extra_exp2_average_reference

Figure 20. Extra experiment. Psychophyscial functions for annoyance of the road traffic reference sounds shown before and after master scaling of annoyance in left and right set of digarams, respectively (arithmetic means and standard error of empirical data).

A graphical illustration of the master scale transformation applied to the annoyance data of panelist 95 is given in Figure 21. The master scale function of the annoyance for the seven sound levels of the reference road traffic noise is plotted in lin-log coordinates and the individual function fitted to these data (full line). The master function (Equation 9) is used for transforming to sound level, the individual annoyance assessments for the target train and road traffic noises (e.g., here the magnitude estimate 70). This same sound level value is then read off on the master function of annoyance (dashed line) and in this case transforms to the annoyance value 55 in master scale units. Every annoyance value of the target noises was transformed this way for each panellist separately. Thereafter, the master scaled annoyance values were averaged after this transformation.

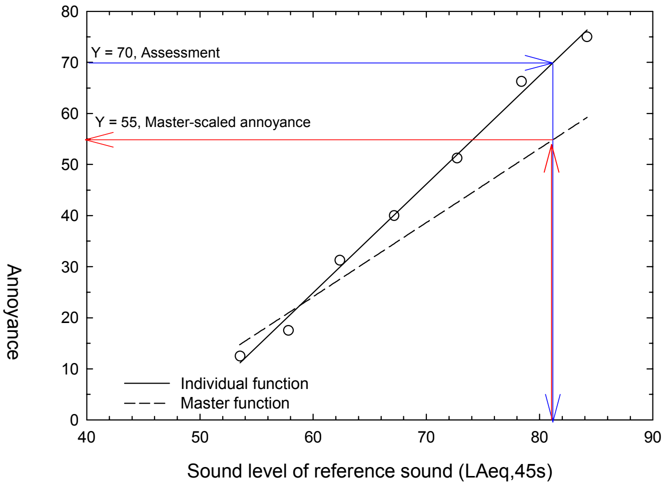


Figure 21. Calculation of master-scaled annoyance, using individual (id 95) psychophysical function of the reference sounds (solid line) and a master function for the same sounds (dashed line).

8. Results

8.1. Versus façade L_{Aeq}

Noise regulation often refer to outdoor exposure and in particular to time averaged (L_{Aeq}) exposure. Therefore, the results are first given as a function of façade exposure. Note that façade exposure is in this case measured 10 cm in front of the (acoustically hard) façade while in calculated noise mapping exercises, it is given without façade reflection taken into account (measured in front of open window). Figure 22 gives an overview of the results of experiment 1. In this and other figures to follow, the dashed line, that indicates the master function can be regarded as the response for the reference road traffic (highway) sound. Figure 23 shows that the additional road traffic noise tests that were performed result in master scaled annoyance values that are significantly closer to the master function than the two identical road traffic sounds RT that were included as a first menu in each session.

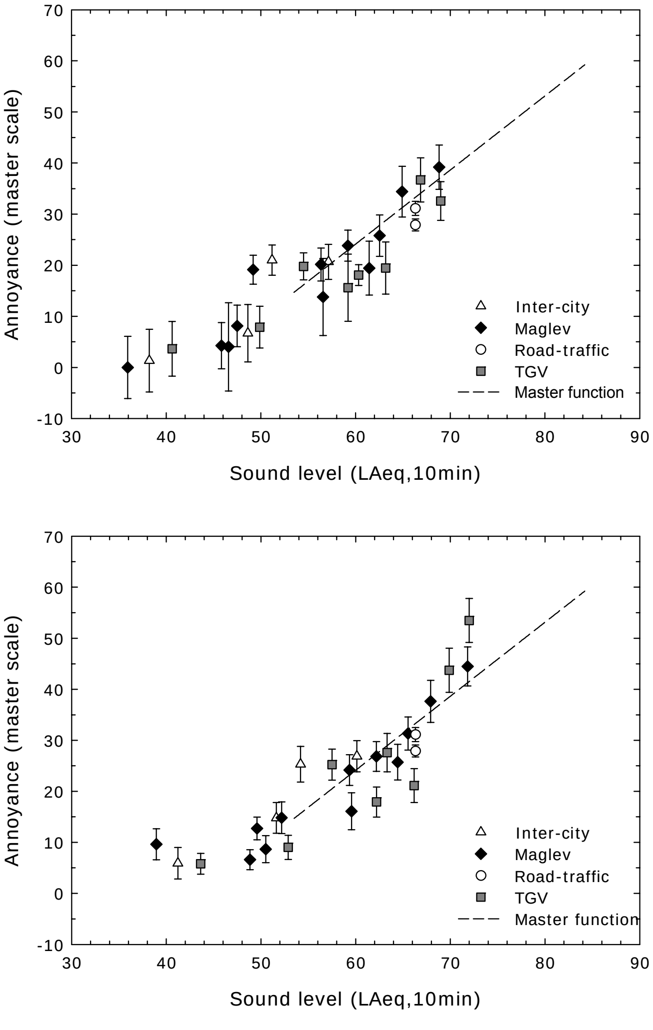


Figure 22. Main experiment: Average master scaled noise annoyance versus $L_{Aeq,10minutes}$ for 2 events per 10 minutes (top) and for 4 events per 10 minutes (bottom) for experiment 1; standard error on means is indicated.

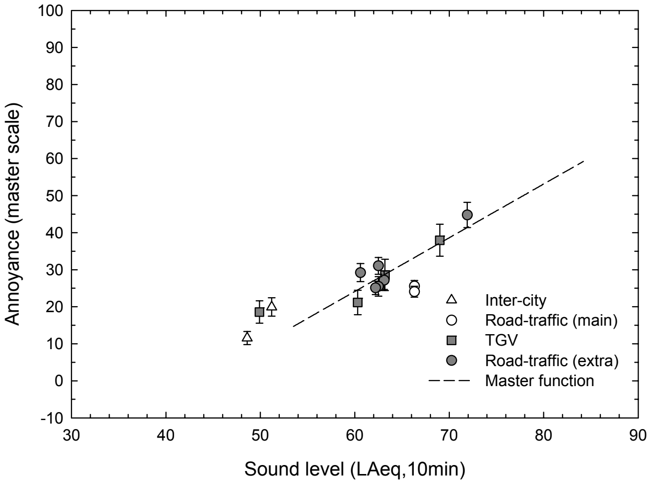


Figure 23. Extra experiment: Average master scaled noise annoyance versus $L_{Aeq,10minutes}$ for additional road traffic sessions (experiment 1); standard error on means is indicated.

From Figure 22 and Figure 23 it can be concluded that the experiment indicates:

- Railway noise is not systematically less annoying than highway traffic noise, but in the LAeq range between 55 and 65 dBA annoyance is lower for particular combinations of distance, vehicle speed, and train type

- Magnetic levitation based transport systems are on the average not significantly more annoying than traditional rail based systems.

The results of experiment 1 also show that L_{Aeq} does not capture all differences in annoyance between different exposures investigated.

In experiment 2 the experimental sounds were presented as a sequence of short (45 second) fragments. Although the question on the answer sheets indicated that the panelist had to assume this sound was heard in another context, it is unlikely that they actually did this since they had been involved in the scaling exercise for several hours when they start experiment 2. Previous research also indicates that in this type of experiment, participants often tend to assess loudness rather than annoyance (as defined in questionnaire surveys). Figure 24 shows that from experiment 2 we can conclude that

- A train passage in general is evaluated at least as annoying (loud) as a 45 second excerpt of highway noise.

- Magnetic levitation and high speed conventional trains are evaluated significantly, but slightly more annoying (loud) than conventional trains and TGV at low speed (the 4 lower dots) once the L_{Aeq} is above 60 dBA.

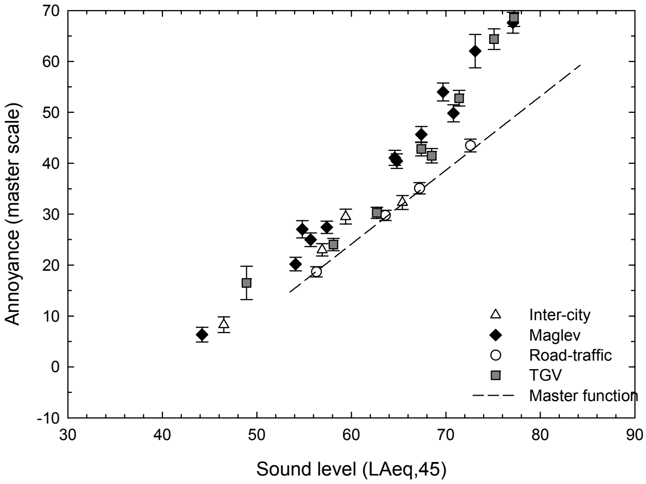


Figure 24. Main experiment: Average annoyance (master scale) versus L_{Aeq} for experiment 2.

8.2. The influence of first exposure

It turned out that there is a significant difference between the noise annoyance assessment in the first and second part of Experiment 1 . In particular, the noise of magnetic levitation (Maglev) trains seems to be more annoying for the same L_{Aeq} if assessed after the exposures to noise of IC and TGV trains (for one hour). Figure 25 shows the train-to-road traffic (master scaled) annoyance ratios, obtained in the same set of menus, as a function of L_{Aeq}. Annoyance of road traffic always refered to 10 min of RT. Compared to Maglev trains, the effect is opposite for TGV trains. This result indicates an annoyance difference which to some extent is due to differences between sessions.

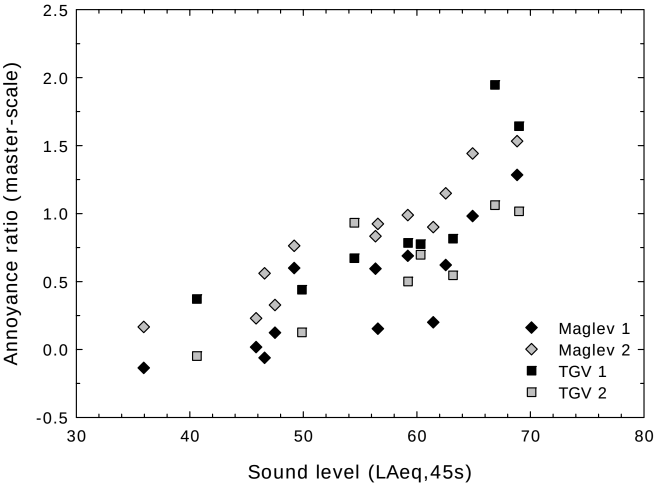


Figure 25. Main experiment: Average noise annoyance relative to road traffic RT in the same set of menus, as a function of LAeq split between the same sounds assessed in the first and the second part of Experiment 1

8.3. Versus Zwicker loudness

Loudness measures such as Zwicker loudness may be better correlated with perceived loudness and noise annoyance. Therefore we also plotted the master scaled annoyance versus Zwicker loudness (Figure 26). The spread in datapoint does not seem to reduce significantly. Note that Zwicker loudness measured indoors may show a different picture.

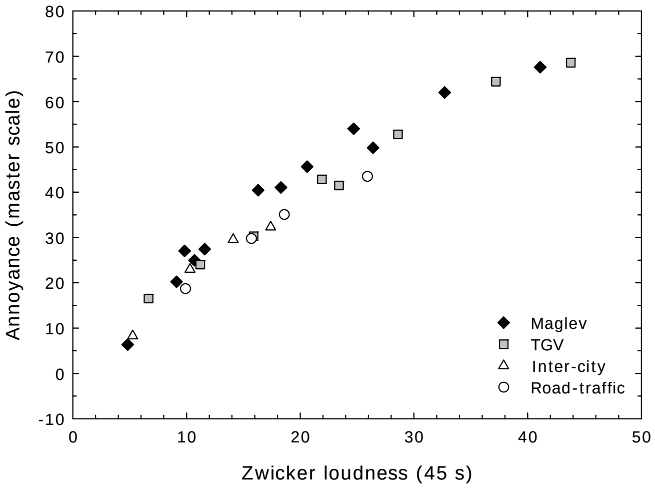


Figure 26. Main experiment. Noise annoyance (experiment 2) as a function of Zwicker loudness at the façade; train and highway noise.

8.4. The influence of distance and speed

As expected, perceived annoyance to train sounds was negatively related to the distance and positively related to speed of the train. For both Maglev sounds and TGV sounds, a weak but statistically significant interaction effect was found. In Figure 27 we focus on experiment 2 (45 second exposure) and show master scaled noise annoyance as a function of distance for different speeds.

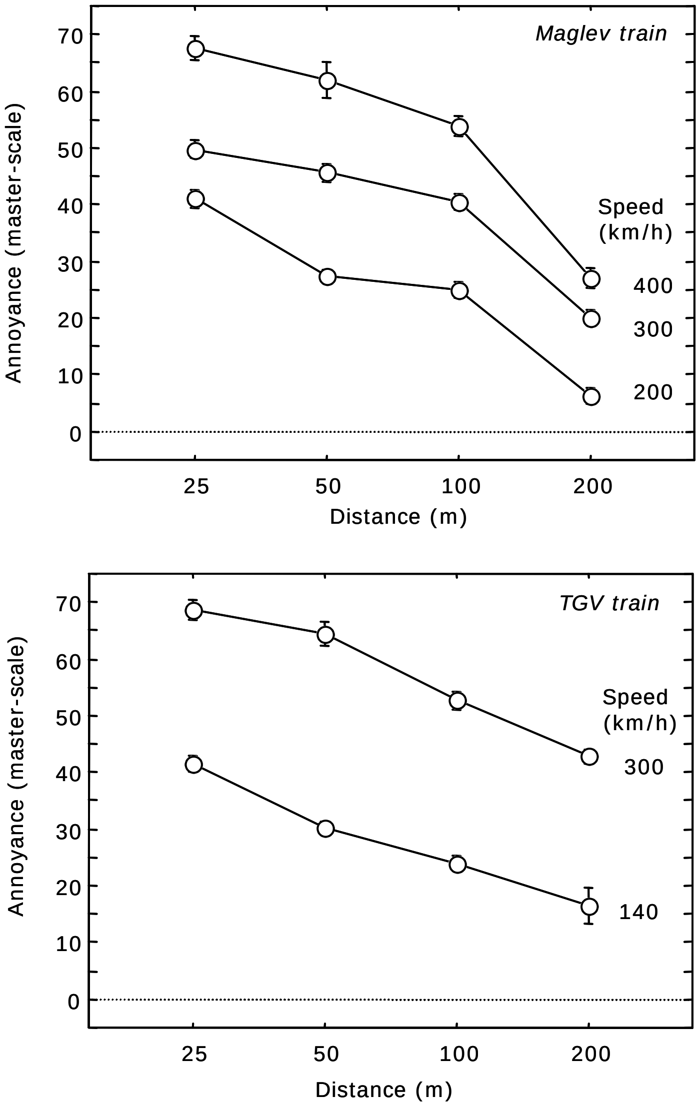


Figure 27 Average annoyances (linear master-scale) as a function of distance and speed for the Maglev sounds (upper panel) and TGV sounds (lower panel) in Experiment 2

Obviously, the effect of distance is to a large extend explained by the decrease of sound level with distance and the increase of sound level with speed. This is illustrated in the Figure 28, showing the sound level of the train sounds ($L_{Aeq,\ 45s}$) as a function of distance and speed. The sound of the Maglev train at 200 m is particularly weak at all speeds. This could be due to a strong directivity of the source combined with attenuation due to interaction of the propagating sound with the ground.

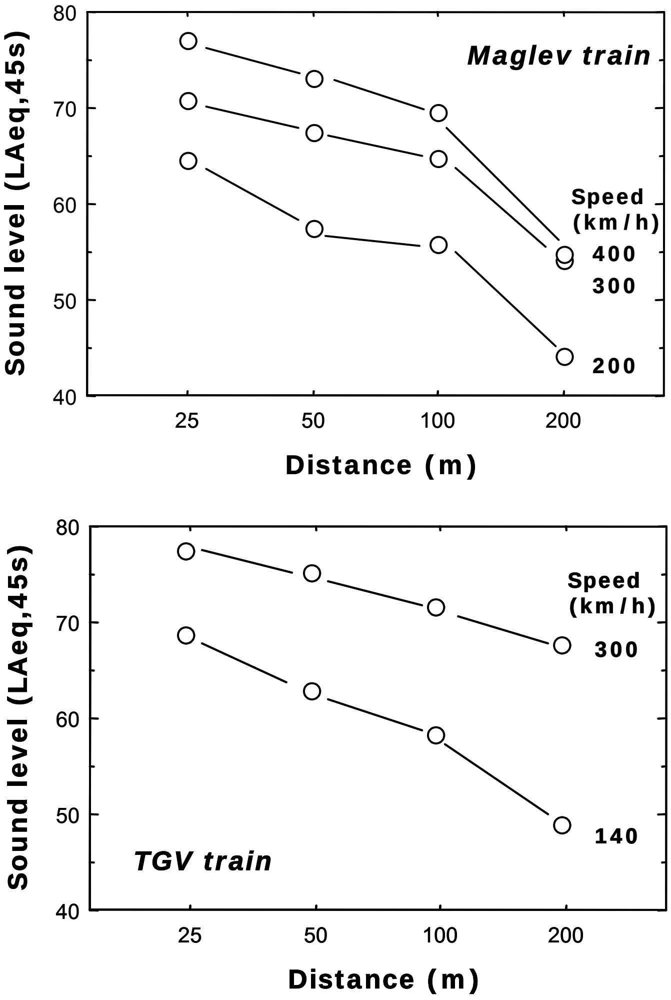


Figure 28. Sound level (LAeq,45s) as a function of distance and speed for the Maglev sounds (upper panel) and TGV sounds (lower panel) used in Experiment 2.

To investigate the additional predictive power of distance and train speed to L_{Aeq}, the possible difference in dose-response curve is highlighted by showing the additional variable as the size of the markers. In Figure 29 the size of the circles is proportional to the distance to the track. For L_{Aeq} between 50 and 65 dBA, annoyance is clearly less for trains passing by at larger distance. This could indicate that the noise annoyance bonus for train noise only holds at larger distances from the track. In Figure 30 the size of the circles is proportional to the speed of the train. High speed does not result in a particular increase in noise annoyance at the same L_{Aeq}.

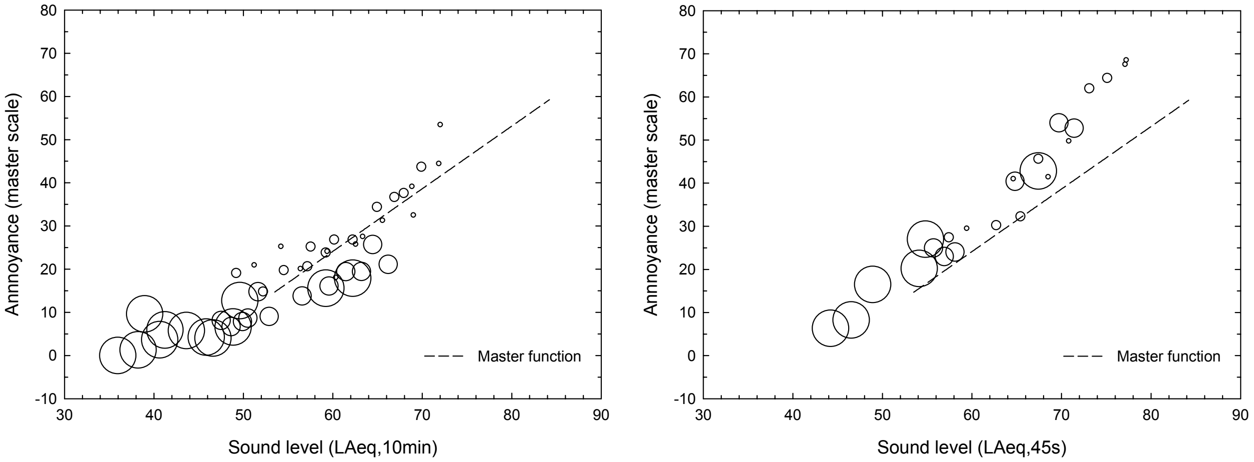


Figure 29. Main experiment: Average noise annoyance as a function of L_{Aeq}, showing four distances to the track as the size of the circles; left: experiment 1; right: experiment 2.

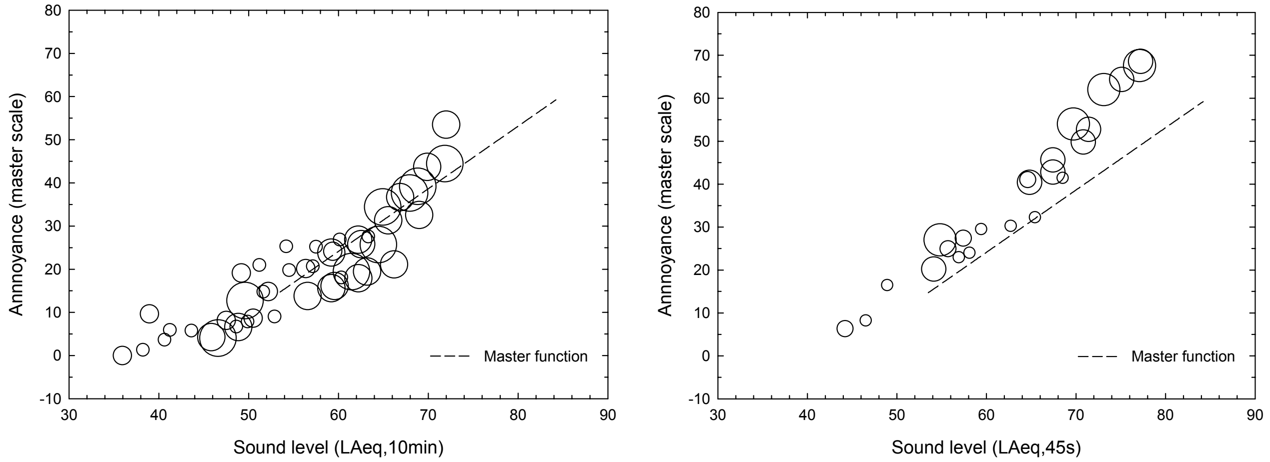


Figure 30. Main experiment: Average noise annoyance as a function of L_{Aeq}, showing vehicle speed as the size of the circles; left: experiment 1; right: experiment 2.

8.5. Annoyance and rise time

Distance to the track and train speed both influence the rate at which the sound level increases when the train approaches. The rise time of a sound event has been mentioned as a factor that can increase annoyance caused by a sound event. The startle effect could explain this increase in annoyance but it was also observed that this is unlikely for trains passing at a distance larger than a few tens of meters. To investigate the effect of rise time, we measured rise speed (dBA/sec) of all the sound events included in this experiment by fitting a straight line through the initial increase in sound level. The fit was performed on a part of the passage that was identified by visual inspection of the event envelope. Table 17 shows the rise speed for each train passage considered. The rise speed of the TGV is higher than that of the MAGLEV for most distances – even at lower speed. In Figure 31 the surface of the circles is proportional to the rise speed. It is clear that rise speed correlates with L_{Aeq}, but there is no clear split of the annoyance L_{Aeq} relationship. At levels above approximately 65 dBA, the trend seems to be stronger than linear while at approximately the same point rise speed starts increasing. The data do not prove beyond any doubt however that this is due to rise time and not due to high level of the event itself.

Table 17. Rise speed (dBA/sec) of the sound events.

Speed/distance	25 m	50 m	100m	200m
MAGLEV: 190, 209, 190, 190 km/h	7,79	5,92	5,06	3,84
MAGLEV: 306, 304, 302, 305 km/h	11,45	9,71	12,88	5,32
MAGLEV: 389, 390, 393, 395 km/h	16,57	15,45	15,34	6,63
≈ 140 km/h TGV	5,27	4,25	4,96	2,75
≈ 300 km/h TGV	22,97	19,00	7,43	8,61
≈ 140 IC	5,12	4,16	5,16	1,46

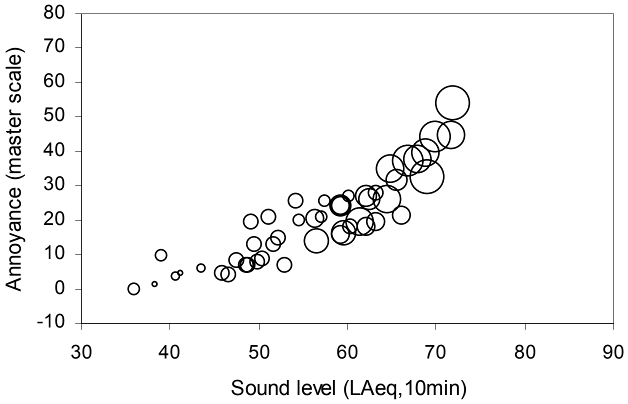


Figure 31. Main experiment: Average noise annoyance as a function of L_{Aeq}, showing the sound event rise speed as the surface of the circles.

8.6. Perceived distance

Auditory perceived distance was assessed in experiment 2. The distributions of distance assessments were strongly positively skewed. The arithmetic means were approximately two times greater than the median distance assessment for each sound. Therefore, group data are shown as medians in Figure 32 below.

Perceived distance was strongly negatively related to sound level (LAeq,45s,), r = -0.88 (see left panel of figure below). For a given sound level, Maglev train sounds are perceived as slightly less distant than are the TGV, inter-city and the road-traffic sounds. The relationship between perceived and physical distance was weaker, r = 0.71. For a physical given distance, the spread in perceived distance was considerable, especially at large physical distance (see right panel of figure below). These results suggest that perceived loudness (related to sound level) was the main cue used for the distance assessments.

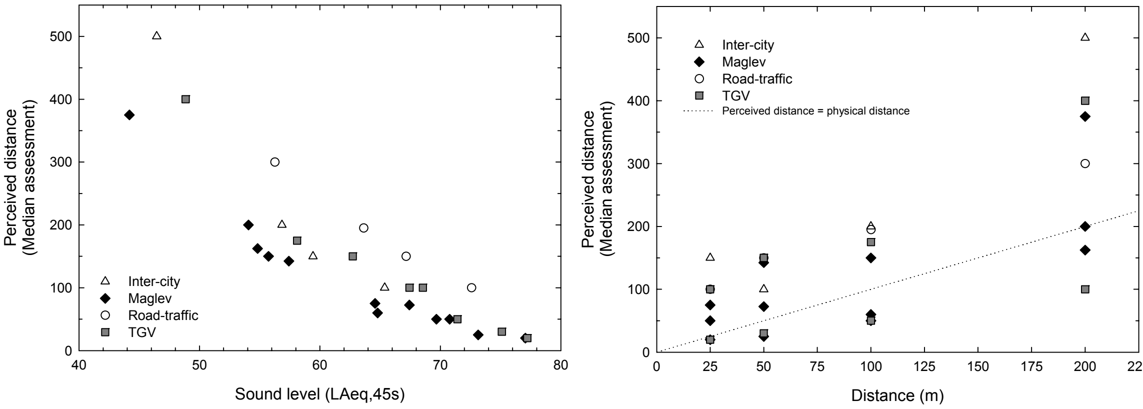


Figure 32. Main experiment. Perceived distance (medians, N = 80) as a function of sound level (left) and physical distance (right). Data from experiment 2.

The general trend of the results from the extra experiment was very similar to the findings of the main experiment. The correlation between perceived distance (median values) and sound level was -0.88, and the correlation between perceived distance and physical distance was 0.76. One difference was that larger perceived distances were given in the extra experiment compared to the main experiment. For example, the median perceived distance assessment of the Inter-city train at a physical distance of 200 m distance was 900 m in the extra experiment and 500 m in the main experiment.

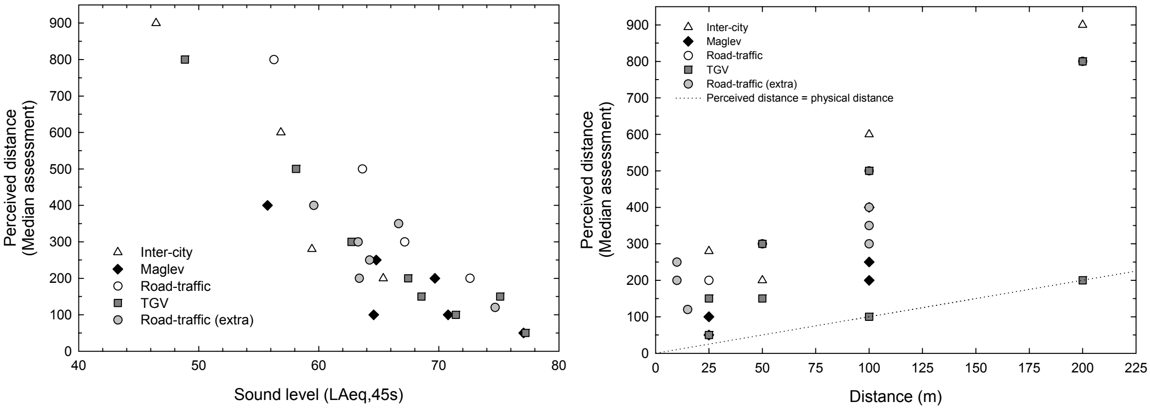


Figure 33 Extra experiment. Perceived distance (medians, N = 21) as a function of sound level (left) and physical distance (right). Data from experiment 2.

8.7. Differences between 10 minute and 45 second exposures (experiment 1 versus experiment 2)

The present listening field experiment was unique in a number of aspects. One important novelty compared to previous laboratory experiments is that participants were asked to judge annoyance over a longer period of time (10 minutes); Fastl and Gottschling (1996) forms an exception. During the 10-min periods, the panellists were engaged in low attention, relaxing activities such as reading a magazine or a comic, drinking coffee, or solving a puzzle. In order to find out how this new approach affects the results, a second experiment was included, which was much more comparable to earlier research (e.g., Vos, 2004). In this section we will for each of the sound fragments. compare each participant's noise annoyance values in experiments 1 and 2. The analyses procedure is as follows:

1. For each sound fragment, remove the panellists that evaluated the annoyance of that sound fragment equal to 0 in experiment 2.

2. For each sound fragment, calculate the ratio of the annoyance value in experiment 1 to the annoyance value in experiment 2. E.g. the ratio between noise annoyance caused by two passages of a Maglev train at 300 km/h at a distance of 100 m to the noise annoyance caused by one passage of that same train in 45 seconds.

3. Calculate a rough distribution over annoyance value ratios: 0, <1, >1.

Results for different sound fragments were clustered based on several criteria. When only train passages are considered, we only find a significant dependence of the people that evaluate the sound in experiment 1 more annoying for the number of passages (Figure 34). The type of train (Figure 35), ASEL per passage (Figure 36), speed, and distance mainly affect the number of people that evaluate the exposure in experiment 1 as not annoying while still giving it a finite level of annoyance in experiment 2.

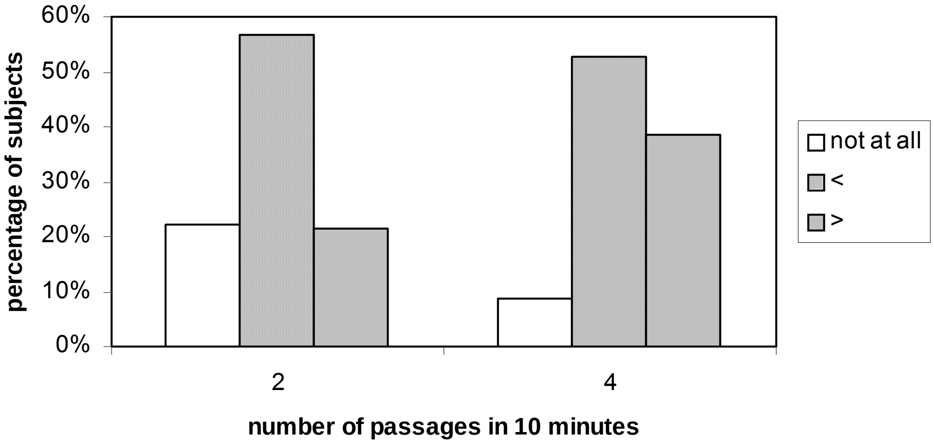


Figure 34. Distribution of the ratio of noise annoyance value in experiment 1 to noise annoyance value in experiment 2 for the same sound fragment: "<"subjects that judge noise annoyance of the same sound lower in experiment 1 than in experiment 2; ">" subjects that judge noise annoyance in experiment 1 higher than in experiment 2.

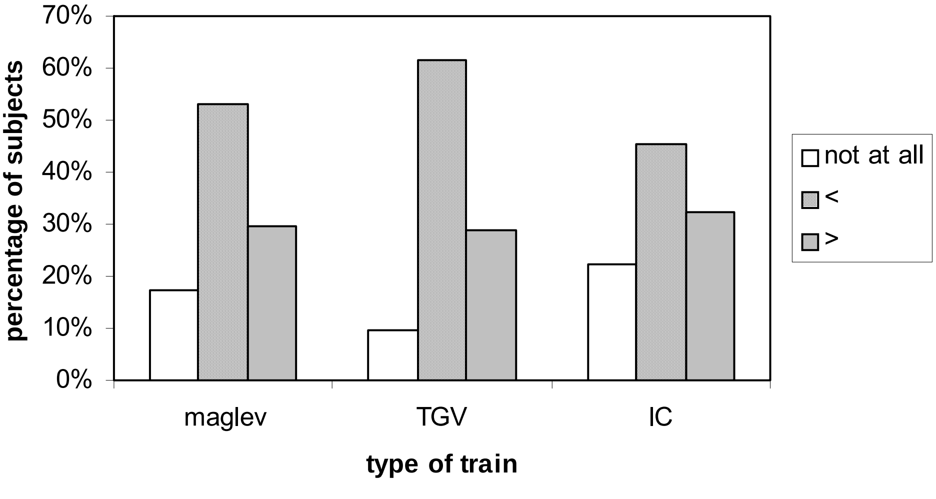


Figure 35. Distribution of the ratio of noise annoyance value in experiment 1 to noise annoyance value in experiment 2 for the same sound fragment: "<"subjects that judge noise annoyance of the same sound lower in experiment 1 than in experiment 2; ">" subjects that judge noise annoyance in experiment 1 higher than in experiment 2.

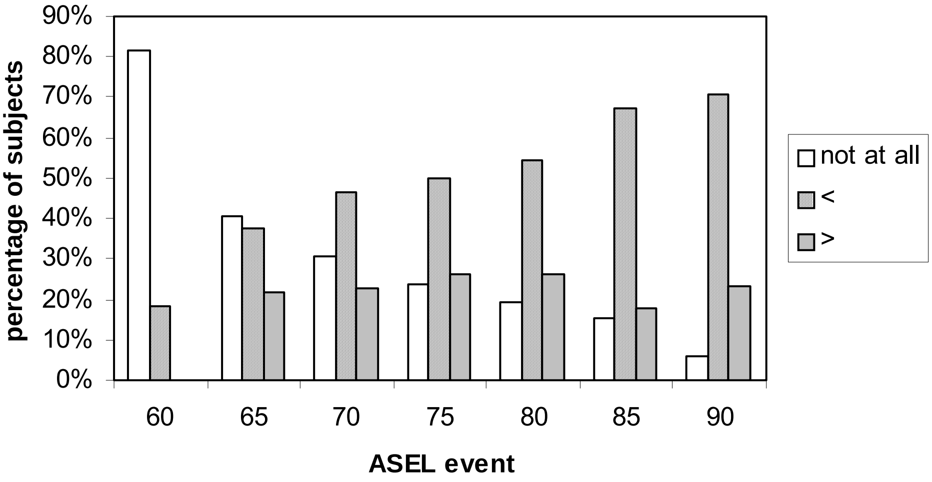


Figure 36. Distribution of the ratio of noise annoyance value in experiment 1 to noise annoyance value in experiment 2 for the same sound fragment: "<"subjects that judge noise annoyance of the same sound lower in experiment 1 than in experiment 2; ">" subjects that judge noise annoyance in experiment 1 higher than in experiment 2.

When experiments with highway sound and other road traffic sound are included in the analyses, additional effects of the type of experiment are observed. For road traffic a larger fraction of the participants in the experiment tends to evaluate the annoyance in the 10 minute experiment more annoying (Figure 37). From a traditional approach where noise annoyance is assumed to depend mainly on the equivalent sound level, this is what could be expected. In Figure 38 the ratio of values is shown as a function of the difference in L_{Aeq} between the exposure in both experiments is shown. The number of participants reporting no annoyance at all in experiment 1 while still reporting at least some annoyance in experiment 2, seems to decrease rather linearly with difference in L_{Aeq}. The number of people value annoyance higher in experiment 1 decreases with difference between L_{Aeq}, but an additional effect seems to play at the lower differences. Note that the difference of -1 dB is road traffic sound while the difference -3 dB is for four passages of trains in 10 minutes.

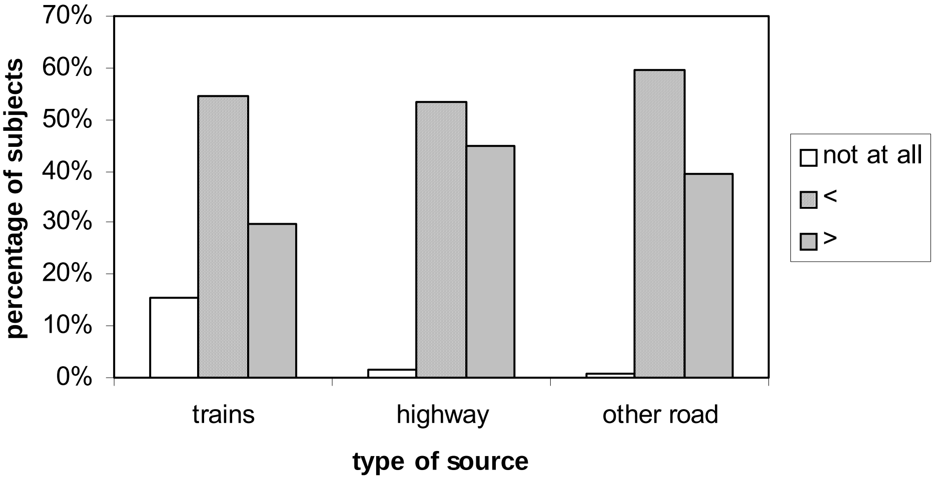


Figure 37. Distribution of the ratio of noise annoyance value in experiment 1 to noise annoyance value in experiment 2 for the same sound fragment: "<"subjects that judge noise annoyance of the same sound lower in experiment 1 than in experiment 2; ">" subjects that judge noise annoyance in experiment 1 higher than in experiment 2.

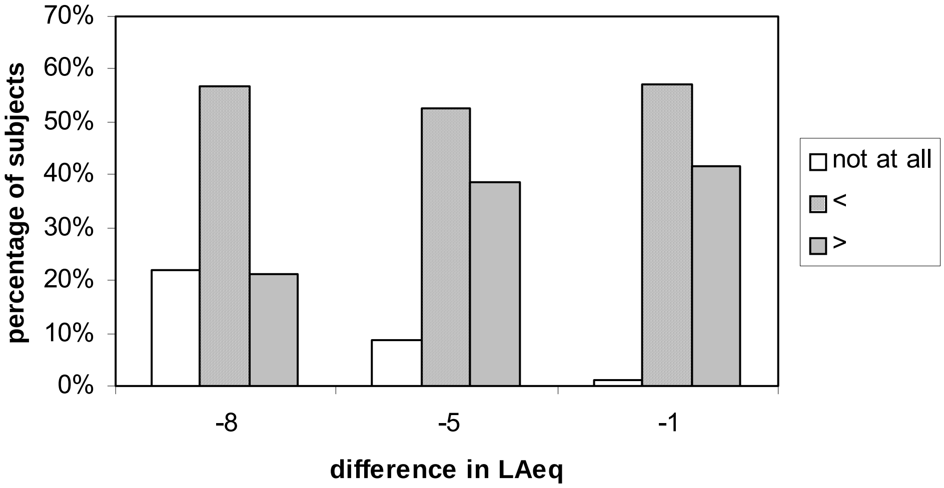


Figure 38. Distribution of the ratio of noise annoyance value in experiment 1 to noise annoyance value in experiment 2 for the same sound fragment: "<"subjects that judge noise annoyance of the same sound lower in experiment 1 than in experiment 2; ">" subjects that judge noise annoyance in experiment 1 higher than in experiment 2.

As an alternative and more condensed representation of the difference between experiment 1 and experiment 2, one can also plot the master-scaled annoyance obtained from both experiments versus each other. This is shown in Figure 39.

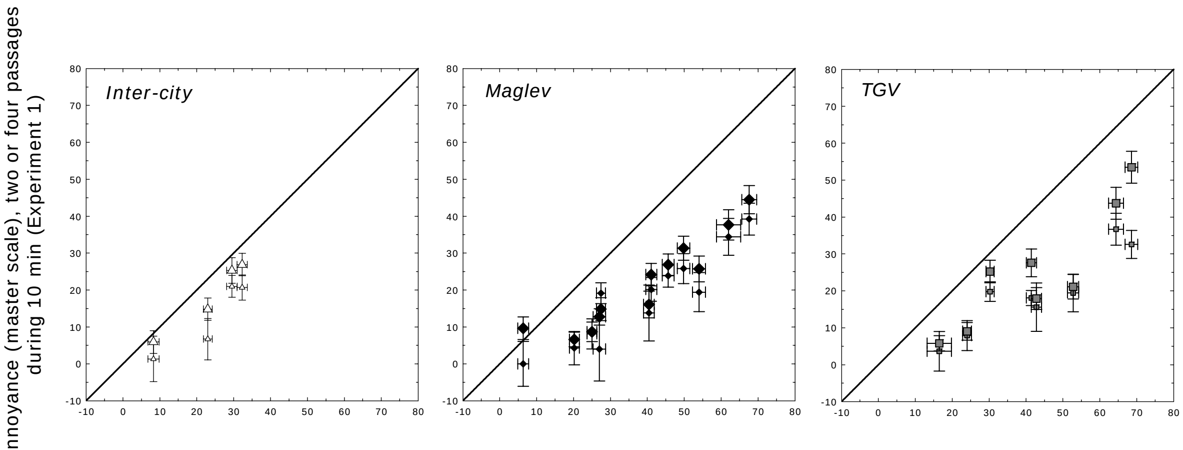


Figure 39. Master-scaled annoyance of two train passages (small symbols) or four train passages (large symbols) during 10 min (Experiment 1) as a function of annoyance of the single 45-s events (Experiment 2).

In conclusion, the experimental procedure based on 10-minute menus, proposed in this study, will mainly affect results in comparison to older work as follows:

- More participants will report no annoyance at all, in fact almost none report zero annoyance in the traditional short exposure time experiment.
- No annoyance will mainly be reported in the new experimental design for (train) sound events. Continuous sound will in general still produce some annoyance (for the sound levels used in this work).

- Only the number of events has a significant influence on the ratio of noise annoyance (higher or lower than 1) in the new and traditional experimental setup. The type of train, the event ASEL, and the speed of the train seems to have a similar effect in both experimental settings (except for the number of subjects reporting no annoyance at all).

8.8. Importance of personal characteristics

One of the reasons for selecting subjects in a representative way was to counter the impact of personal non-acoustic factors that may influence perception of noise annoyance. A posteriori a few factors generally quoted in literature as being important for the perception of noise were investigated in more detail. As all subjects are exposed to exactly the same 10 minute road traffic sound (R2) at the beginning of the two listening sessions in experiment 1, the response to this sound was used for analyzing the impact of personal factors.

Reported noise sensitivity

Noise sensitivity as reported by the subjects in the repeated part of the questionnaire at the end of the experiment (question 22, B5_2) is chosen as a predictive variable. Figure 40 shows the noise annoyance obtained from experiment 1 as a function of this sensitivity. A significant trend is observed. A cumulative normal distribution seems to predict the dependence.

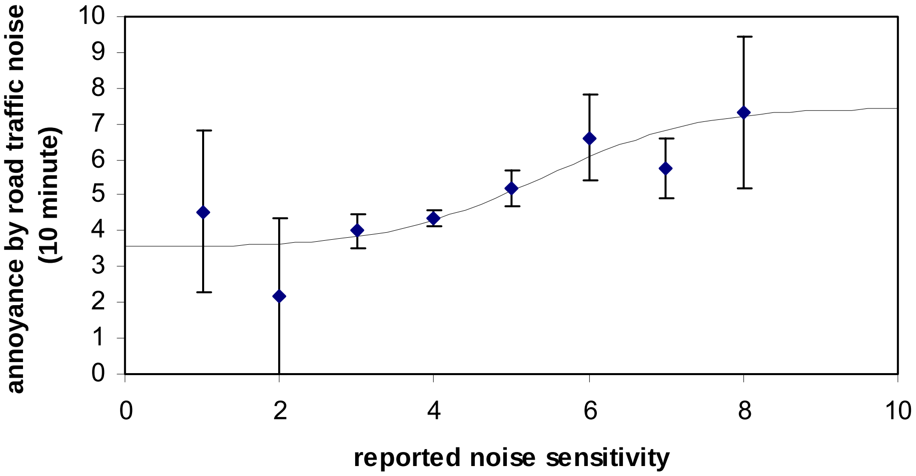


Figure 40. Annoyance[1] *by 10 minute exposure to road traffic sound (average of two tests) as a function of on-site reported noise sensitivity; error flags give standard-error on mean; trend line is shifted cumulative normal distribution.*

Trait anxiety

Trait anxiety is assessed in the questionnaire by asking about the occurrence of situations where the subjects are scared or afraid (question 29, A3_2). Figure 41 shows that the trend is in this case less clear. If any, the trend could be that people that report never being afraid (0) and those that report quite often being afraid (>4) respond more moderately to noise (the outlier for 6 is conveniently ignored). Note that the most participants (53/80) are in categories 1 to 3.

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[1] Linear-response-versus-dB master scaling was used to extract the annoyance rating.

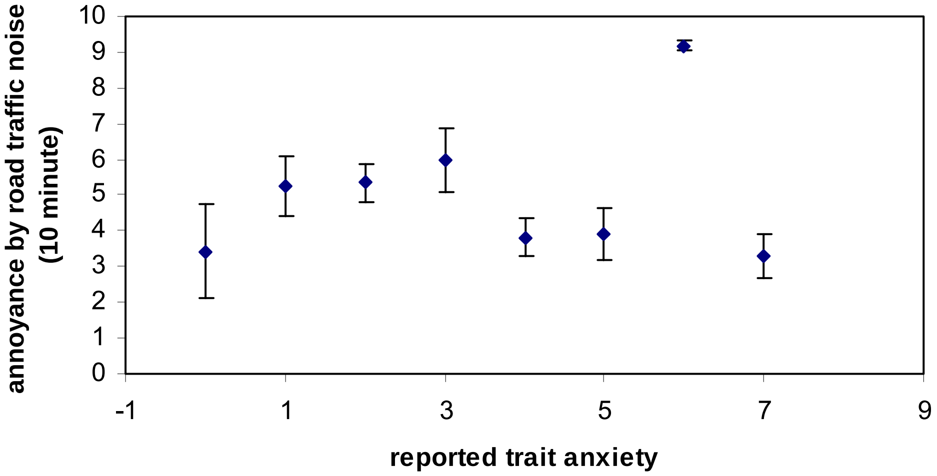

Figure 41. Annoyance[2] *by 10 minute exposure to road traffic sound (average of two tests) as a function of on-site reported trait anxiety; error flags give standard-error on mean.*

Expected influence on quality of life

The expected influence of noise on one's quality of life (question 25c, B3_2) may influence the way noise is perceived. Figure 42 illustrates that this potential effect is not significant in this experiment.

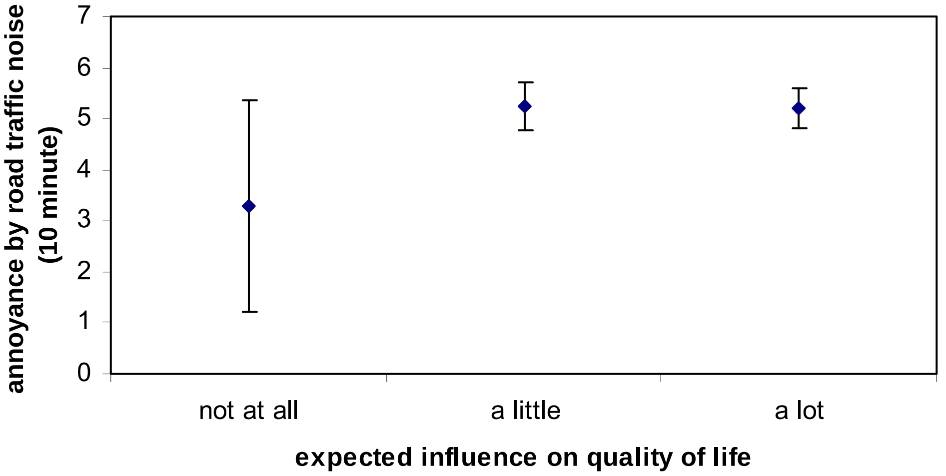

Figure 42. Annoyance[3] *by 10 minute exposure to road traffic sound (average of two tests) as a function of on-site reported expected influence of noise on one's quality of life; error flags give standard-error on mean.*

Environmental worry

General worrying about environmental issues is assessed by question 20, B2 in the part of the selection questionnaire repeated at the end of the listening tests. Figure 43 shows a significant dependence of the reported noise annoyance after 10 minute exposure to road traffic sound. The numbers used for averaging

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[2] Linear-response-versus-dB master scaling was used to extract the annoyance rating.

[3] Linear-response-versus-dB master scaling was used to extract the annoyance rating.

the response were : 0=not at all concerned; 1=not very concerned; 2=somewhat concerned; 3=very concerned.

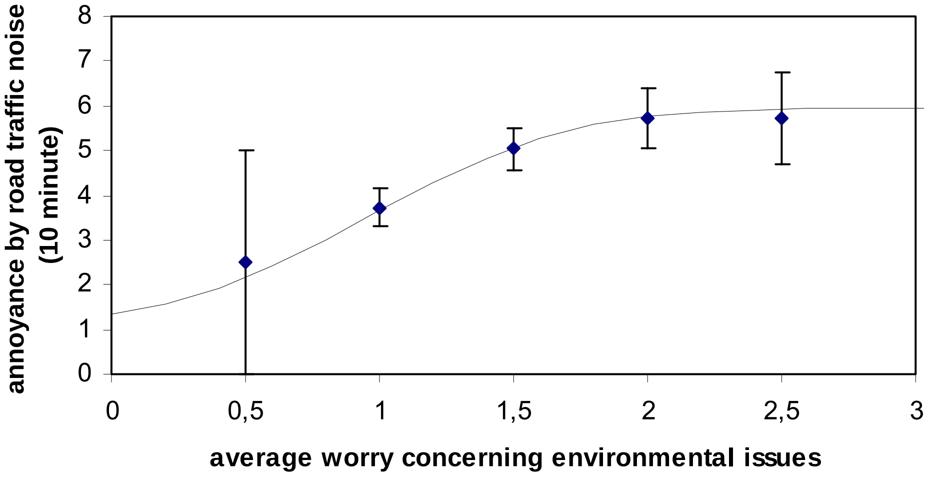

Figure 43. Annoyance[4] *by 10 minute exposure to road traffic sound (average of two tests) as a function of on-site reported worry concerning environmental issues (arithmetic average); error flags give standard-error on mean; trend line is shifted cumulative normal distribution.*

In conclusion, a significant trend can be found for two of the reported personal characteristics investigated: noise sensitivity and environmental worry. This does not imply that there may not be other significant relations. It proves that:

- It is usefull to check for the most important personal factors when selecting a test panel for noise annoyance experiments.
- The master scaling procedure does not seem to eliminate all of the personal factors that may influence the perception of annoyance over a longer time period.

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[4] Linear-response-versus-dB master scaling was used to extract the annoyance rating.

9. Discussion of the results

The present field experiment differs from earlier noise annoyance studies in several innovative aspects which were proposed in our offer upon request. Consequently, we believe that our results are unique and close to residents' everyday reality, although comparisons with results in the literature is somewhat limited. The innovative aspect are:

- Virtual-reality reproduced outdoor transport-noise exposure of a house, utilizing its natural outdoor-to-indoor sound transformation characteristics (slightly open window) for providing a *realistic sound environment indoors*, transport sounds inclusive.
- Unique screening procedure for selecting participants, utilizing their response profiles in an environmental health questionnaire compared to a nationwide questionnaire survey, for obtaining *panelists representative of the Dutch population*.
- Four-hour field experiments, during which subgroups of panelists were kept indoors, and upon request reported *annoyance to transport noise with reference to 10 min or 60 min periods of exposure* (whilst relaxing and reading) but also to shorter more conventional 45 sec exposures (whilst listening).
- Panelists' assessed *noise annoyance to transport sounds by master scaling*, utilizing seven reference sound levels of road traffic noise (a) for providing the same empirical scaling context, (b) for measuring on a defined master scale, and (c) for comparing transport noise annoyance within and between studies, future inclusive.

A main goal was to investigate the difference in perceived noise annoyance caused by magnetic levitation trains compared to high speed conventional trains (TGV) and modern IC trains. A main goal was to assess degrees of perceived noise annoyance with reference to "longer" periods of time-table realistic train passages (10 min, 1 h), than is common in psychoacoustical laboratory experiments (seconds), (45s Maglev in Vos, 2004); Fastl and Gottschling (1996) form an exception (15 min Transrapid). A psychoacoustical "quasi-experiment" in the field (cf. Cook & Campbell, 1979) was chosen rather than a conventional annoyance questionnaire study (for reviews on railway noise, see Moehler, 1988; Miedema & Vos, 1998). The latter being impossible for systems that are not yet used on a large scale. The advantages of experimental control *and* natural field conditions were sought (being together in a living room of somebody's home). These requirements all affect our choice of method for measuring noise annoyance on at least an interval scale and preferably a ratio scale (Stevens, 1946; Marks & Algom, 1998).

9.1. Choice of method for scaling noise annoyance

Long-term annoyance in questionnaire surveys are typically assessed on category scales (e.g., with reference to last month or last year; e.g., Miedema & Vos 1998; Miedema & Oudshoorn, 2001). Fields et al. (2001) has published a consensus on an internationally recommended noise annoyance question including response categories. Vos (2004) used his own "response format" in his psychophysical experiment on short-term annoyance of Maglev noise (9 vs. 10 categories). In category scaling, a response category is assumed to be identical for every participant (by verbal labeling of end-points or every response box); also the inter-category intervals are assumed to be the same (e.g., Baird & Noma, 1978). As shown by Berglund et al. (1975a, 1975b) this assumption does not hold true; for example, in questionnaire surveys respondents' response criteria (scale value of category borders) for annoyance are much higher for respondents in low noise areas as compared to those in highly exposed areas.

The most well known scaling bias in laboratory experiments is the context effect in which participants i.a. will distribute their responses over the "full" range of categories independent of the size of the exposure range, be it small or large (cf. Poulton, 1989; Marks, 1994; for a review see Marks & Algom, 1998). In the process of using category scales, floor and ceiling effects on annoyance may also appear (potential interpretation of annoyance functions by Versfeld & Vos, 1997). To avoid such effects, an invariant sound-level range of references was used as "annoyance context" in every part of the main and extra field listening experiments (Training session1 for Experiment 1, part 1, Training session 2 for Experiment 1, part 2 and in Experiment 2). We choose continuous road-traffic noise as reference sound instead of multiple event sounds because it is simpler to reproduce in future studies. As regards "annoyance context", another type of multiple event sound may have served us better, although Berglund and Berglund (1986) found that pink noise worked equally well as “loudness context” for impulse sounds from large and small-bore weapons, as a set of sound levels of one type impulse sound.

To avoid the scaling bias of category scales, the method of magnitude estimation was chosen in which participants were free to use the range of numbers they felt comfortable with. Master scaling was applied to these individual annoyance estimates, involving a transformation function to a common master scale defined by the references. The reference sound levels of road traffic noise also defined the scaling context (e.g., Berglund, 1991a). In theory, this master scale transformation (based on the annoyance of reference sounds levels) will calibrate the “loudness-based” noise annoyance, whereas the relative contribution to noise annoyance from qualitative content (e.g., type of sound, time pattern, cues for speed and distance) will hopefully be unchanged. The master scaling approach was necessary because experimental time would have been too long for all panelists to scale all transport noises (in 10 min menus).

Earlier research has shown that master scaling with references works well for loudness or annoyance of a one-occasion target exposure, that is when repeated exposure is unrealistic (e.g., large experiments) or nonexistent (e.g., questionnaire surveys). Illustrative examples are given in Berglund et al. (1983), Berglund (1991a), Berglund and Job (1996), Berglund and Nilsson (2000, 2004). Berglund et al. (1983) showed that the master scale power group transform of loudness was superior to equalizing different subjects’ grand mean loudness of references (originally proposed by Lane et al., 1961). For the loudness of repetitive sounds, Berglund and Nordin (1992) showed that master scaling would reduce the interindividual variability in loudness close to the size of the intraindividual variability as assessed by the coefficient of variation (standard deviation divided by the mean). Individual variation in the perception of qualitative content would potentially be preserved if larger coefficients were obtained between than within subjects.

Although a methodological study of master scaling of annoyance was not at focus in the present field experiment, we believe that the results obtained are favorable compared to the results we would have obtained by category scaling. The test-retest reliability of the 101 panelists’ magnitude estimates of annoyance of the 45-sec reference sound levels was found to be very good (between 0.76-0.88) compared to Vos’s (2004) reliability of 0.72 for a group of 12 much younger subjects (also annoyance of 45-sec train and road sound fragments). Considering that our panelists all were naïve participants, they also each produced high quality psychophysical functions for the reference (cf. Kuwano, Namba & Miura, 1989).

9.2. Annoyance of one train passages (45 sec) give no support for differenciating between Maglev and TGV/IC trains

Because of differences in method, absolute annoyance values are not possible to compare between our field experiment’s 45 sec Maglev noises and the 45 sec Maglev noises in Vos’s (2004) experiment. Although the quality of the Maglev recrodings (mono as contrasted to stereo) also differed, it is of course possible to compare telative annoyance of different 45-sec one train passages, For example, annoyance of Maglev and TGV at similar speed and distance. Vos (2004) train passages varied in sound exposure level (ASEL) but the influence on annoyance of distance to source (propagated noise) or of speed cannot be well separated (see combinations studied by Vos in Table 18). For example, for IC trains the ASEL variation was 10 dB at 100 m (due to 120-130 km/h speeds and/or length of train) whereas Maglev train passages varied 15 dB at 100 m due to speed only (100-400 km/h); distance to source created a 10-15 dB variation at constant speeds. It may be that although the train passages were equal in ASEL, perceived noise annoyance may differ because of differences in spectra or time domain. In the present field experiment, the influence on annoyance of the propagated noise at the same four distances was assessed for approximately invariant speed (three speeds for Maglev, two for TGV and one for IC, see Table 2). For the three types of train, Maglev, TGV and IC, the outdoor range of the ASEL was 33, 28 and 19 dB as compared to Vos’s (2004) 25, 15 and 15 dB, respectively. The total ASEL range was however similar, between 62 and 92.8 dB in the present experiment and between 60 and 90 dB in Vos’s experiment.

Our results for one-train passages (45 sec) in both the main and the extra field experiment (Figure 22 and Figure 23, respectively) essentially confirm the results of Vos (2004) for *high speed trains* (open-window condition). By adding 16.5 dB to the LAeq,45 dB values on the abscissa in our two figures, ASEL values are obtained which are comparable to Vos’s ASELs. Whereas Vos’s annoyance functions are linear in lin-log coordinates ours show a slight curvilinearity. This may result from the principle of selecting stimuli from a matrix of six “type/speed” *times* four “distances” (where “type/speed” refers to three types of train run at 3, 2 and 1 speeds, representing four unique speeds) combined with an interaction effect on annoyance. This interaction would be strong for, for example "low speed, long distance" and "high speed, short distance" but relatively weak for the very "unequal" combinations. For example, long distance does not substaintially interact with high speed to enhance annoyance caused by train speed. An alternative explanation for the curvilinearity, is that the annoyance function for our train noises is a power function rather than a logarithmic function (plot is in lin-log).

Table 18. Vos's (2004) data organized with regard to selection of SEL based on interaction effects on annoyance of speed and distance (recorded sounds).

Speed/distance	25 m	35 m	50 m	100 m	200 m	**Range**	**Total range**
100 km/h	80 dB		75 dB	65 dB		**15 dB**	
200 km/h	80 dB		75 dB	70 dB		**10 dB**	
325 km/h	90 dB		85 dB	75 dB		**15 dB**	
400 km/h	90 dB		85 dB	80 dB		**10 dB**	**25 dB**
Range:	**10 dB**		**10 dB**	**15 dB**			
≈ 300 km/h TGV			85 dB		75 dB		
≈ 300 km/h TGV			90 dB		80 dB	**15 dB**	**15 dB**
Range:			**5 dB**		**5 dB**		
≈ 130 km/h IC		90 dB		75 dB			
≈ 130 km/h IC				80 dB			
≈ 130 km/h IC				85 dB		**15 dB**	**15 dB**
Range:		**0 dB**		**10 dB**			

The 45 sec road traffic noises used in the present and Vos's (2004) experiments were different in character. Vos combined 10-12 passenger cars with one truck (recorded at 12.5, 25 and 60 m; attenuated), whereas we used free flow highway traffic (at 25, 50, 100 and 200 m) in the main experiment and these combined with additional road traffic noise from local roads (low, medium and high intensity, each at 25 and 100 m) in the extra experiment. Again, by adding 16.5 dB to the LAeq,45 dB values on the abscissa in our two Figures 10 and 11, ASEL values would be comparable to Vos's ASELs. The ASEL range of our road traffic noises was between 71.8 and 90.2 dB and Vos's between 65 and 85dB. Although the ranges were similar (ca. 20 dB), our range was placed in a higher region than Vos's and should therefore be lower in annoyance than the high-speed trains, approximately from 80 dB ASEL and up (corresponds to 63.5 dB LAeq,45s in Figure 22 and Figure 23). Clearly, road traffic seems to be less annoying than high-speed trains from this sound level and up (ca. 65 dB LAeq,45s). This result does not support a 5-dB railway bonus for high speed trains, but rather suggests a slight penalty relative to road traffic noise at high exposure levels.

Our 45 sec IC trains were close to equally annoying as the high-speed trains (Figure 22 and Figure 23), whereas Vos's IC trains were perceived to be distinctly less annoying. One reason for this difference is that the sound exposure of our IC trains were lower than Vos's IC trains (62-81 dB vs. 75-90 dB ASEL) combined with the fact that the annoyance function for IC trains has a much lower slope than for high-speed trains in Vos's data (= large annoyance difference at higher exposure levels). However, Vos's road traffic noises were in a lower exposure region than ours (both 20 dB range) and were at equal exposure level found to be equally annoying as the high speed trains and clearly more annoying than his IC-trains. Conversely, our road traffic noises were in a higher exposure region and were at equal exposure level found to be less annoying than the high-speed trains and marginally less annoying than the IC-trains which were in the lower exposure region. Obviously, the probability for finding significant annoyance differences between transport noises increases with the (equal) sound level at which they are compared. However, our annoyance data suggest a small railway penalty, not a railway bonus.

There are several reasons why other investigators have found a railway bonus (for review see Miedema & Vos, 1998), that is not present in the current field experiment. One of the reasons for finding a railway bonus for short (one minute) noises in listening experiments may be that the relation between loudness and L_{Aeq} is different for train and road traffic noise. Indeed, some researchers have argued that noise annoyance evaluation in listening tests of short sounds actually is close to a "perceptual loudness" evaluation (however, see Berglund, 1991b, on differences between loudness-based vs. quality-based perceived annoyance). If Zwicker loudness is a good first estimate of perceptual loudness (of stationary sound, e.g., Zwicker, 1989), the difference between train and road noise may be seen in a Zwicker loudness versus L_{Aeq} plot (Figure 44). Because the IC train noise used in the experiment was the noise of modern rather quiet trains (IC new), a few more noisy train models (IC old) were added in this acoustic analysis. At levels above ca. 65 dBA, TGV and Maglev trains seem to be a little louder than road traffic or IC trains (IC old), but this effect is not significant enough to support the current 5-dB railway bonus.

Interestingly, the results of Figure 44 shows that Zwicker loudness and sound level are approximately linearly related for transport noises below 60 dB LAeq.45s. At higher levels the relationship is curvilinear and road traffic and old IC trains are distinguished to be slightly lower in Zwicker loudness at equal sound level. These results seems to mimic the results for perceived noise annoyance.

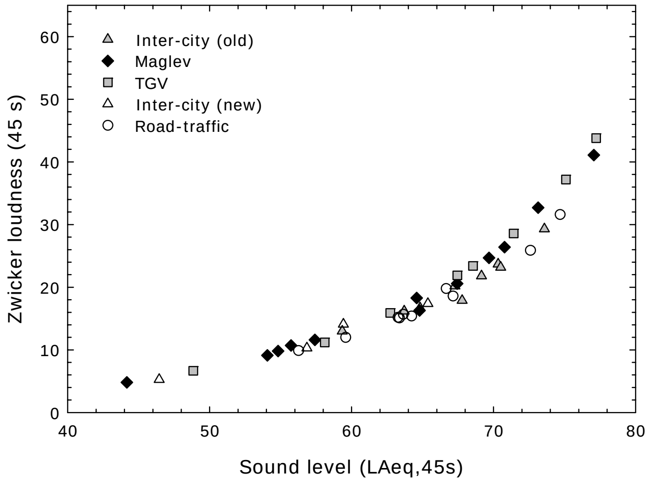

Figure 44 Zwicker loudness versus LAeq for the sounds investigated and for some additional noisier IC trains (IC old).

9.3. Annoyance of several train passages separated by quiet intervals

It should be pointed out that the annoyance reports of 45-s train passage is higher that the annoyance report of two such train passages within the 10 min menus. This is all in order, although the two types of annoyances were master scaled in order to become comparable over experimental sessions. First, when judging 45-sec train passage immediately after it was heard, it is quite clear that the task is to assess the annoyance of that particular train passage (or other sounds that were presented). However, when asked to assess the annoyance, retrospectively, of the transport noise (e.g., two train passages) that happened during the last 10 min, the panelist will have to choose a strategy how to go about this. For example, only refer the annoyance to the two "noise-on" periods ("limited" to noise stimulus) or refer the annoyance to the whole 10 min period ("expanded" duration or "diluted" level) In addition, the noise annoyance of two overlapping (equal) noises would be expected always to be less than the arithmetic sum of the two annoyances (for a review see Nilsson & Berglund, 2001). It is more uncertain how total annoyance of two train passages separated in time will actually be acquired.

Based on empirical data on successive tones and noises, Nilsson (2001) proposes that only within the time span of our psychological present or feeling of "nowness" (3 s according to, e.g., Pöppel, 1997; Kuwano, 2002) can total perceived annoyance exist together with separate-sound annoyances, and total annoyance thus be crated by a sensory-based mechanism (believed to be arithmetic annoyance summation). For longer sounds, an overall annoyance may not exist as a mere perception. Instead, total annoyance requires a strategy (conscious or nonconscious) by which the panelist combines annoyances from "previous " sounds not directly available in the psychological present. When a total annoyance response is required, the panelist somehow retrieve annoyance components from memory and combine these cognitively. The situation for our panelists were close to the latter case. They would then have passively registered the sounds heard and upon request later on responded with a value they intuitively found appropriate for the total annoyance of the two train passages. The outcome will then be a value predominated by the louder sound in the combination and/or the most recent sound heard (Nilsson, 2001). None of these two factors would have influenced our annoyance reports because the two (or four) train passages were constructed to be identical. The panelists were instructed to make intuitive assessments and they all reported annoyance of four (or two) successive train passages in 10 min to be less than the one 45-sec passage. All our knowledge implies that the panelists were retrospectively "averaging" annoyances of the transport sounds they had heard when reading and relaxing.

As expected for the 10 min menus, the annoyance of four train passages was found to be greater than the annoyance of two train passages. This doubling of number of trains (Maglev, TGV, or EC) corresponds to an increase by close to 5 master-scaled annoyance units independent of annoyance level. This corresponds to a 3.45 (±0.65SE) dB increase in road traffic noise equivalent sound level (LAeq,45sec). That is, within the 10 min menus, a doubling of the number of the same 45-sec train passage from 2 to 4 approximately translates to sound energy summation of road traffic noise. In comparison, a doubling of number of road vehicles (=2 times greater acoustic emission) would as a rule of thumb be translated to 3 dB increase in traffic. Consequently, a doubling of the number of trains would correspond to an annoyance increase resulting from doubling the number of vehicles in free flow road traffic. Furthermore, since annoyance of 2 and 4 train passages (10 min menus) showed an accelerating curvilinear trend against sound level of train passages, annoyancewise a 3.45 dB increase means more at higher train sound levels than at low train sound levels. This would be in disfavor of high-speed trains as compared to conventional trains, because the former typically produce higher train sound levels.

9.4. Contribution to annoyance of train speed and distance to track

For the high speed train passages, increase distance to track (25-200 m) was found to reduce annoyance to a larger extent than lowering the speed (Maglev 400-200 km/h; TGV 300-140 km/h). There were also significant interaction effects of distance to track and speed. In noise propagation, geometrical spreading, air absorption, ground effect and atmospheric turbulence will all contribute to changes in sound level as well as qualitative characteristics of the sound. As pointed out by Preis and Golebiewski (2004), it is well known that these factors will create differences in annoyance which thus also can be explained by loudness differences due to distance. The critical question is however to what extent annoyance to propagated noise is determined by qualitative differences such as spectral content, rise speed, etc.

Since a nice accelerating curvilinear relationship was found for our set of train passages for Zwicker loudness as a function of LAeq,45sec, equal sound level produces approximately equal Zwicker loudness. This is somewhat surprising since Zwicker loudness is intended for stationary sounds and not mobile sound. Compared at equal sound level (or approximately equal Zwicker loudness), neither speed of train nor train rise speed resulted in higher annoyance. However, there is still a significant interaction effect on annoyance from distance to track and speed. Obviously, good annoyance models are lacking which take into account the propagation of sounds from moving sources. Our results clearly show that annoyance change due to distance to source cannot be exchanged for sound level change due to distance to source. Another interesting factor we know little about is the effect of length of train and distance to track on annoyance.

9.5. Perceived distance to railway track

In the research literature, auditory distance is the common term used for perceived distance to source (Coleman, 1968; Strybel & Perrott, 1984; Little et al., 1992). Propagated noise is geographically spread and decreases in sound level. When the sound level of moving sounds decreases, we perceive an increase in distance. In addition, the air will selectively more absorb high frequencies relative to low frequencies, which also produce a perception of increased distance. The perceived distance (in meters) as a function of geographical distance (in meters) is close to linear, but with a very wide spread which becomes larger at larger distances (e.g., 200-m spread at 100-m physical distance). At all distances but 50 m, the inter-city trains are perceived relatively farther away than the high speed trains. Sound level was demonstrated to be a main cue to auditory distance for all the sounds, however, qualitative content distinctly separate the four types of noise (Maglev, TGV, IC and road traffic). Thus, at equal sound levels, the tracks of Maglev noise passages were perceived to be closer than that of TGVs and ICs which in turn were perceived to be at similar distance, and the highway was perceived to be farthest away. It seems that the higher the sound level, the less is the contribution to perceived distance of qualitative sound content. Obvious cues were the differences in spectral content of the transport noises, particularly changes in the low and middle frequencies, possibly due to air turbulence and ground effects (e.g., Embleton, 1996).

9.6. Summarised comparison to earlier studies concerned with annoyance caused by magnetic levitation trains

Prior to this study, annoyance caused by magnetic levitation trains was studied by Vos (2004) by Neugebauer et al. (1997) and by Fastl and Gottschling (1996). The first two studies concluded that the sound produced by magnetic levitation trains was significantly more annoying than the sound produced by conventional trains. Both studies however used short single passage evaluations. The experiment by Fastl and Gottschling (1996) used longer durations more comparable to the test sounds used in Experiment 1. They found that the test panel's noise annoyance could not distinguish between conventional trains and maglev trains.

Since the experiments mentioned above used different methods for measuring annoyance, it is dubious to compare results directly. To improve comparability, a linear scale transform which matches the outcome for the maglev trains was applied to the annoyance scales used in the three studies. Figure 45 shows the resulting relationship for annoyance versus SEL of one passage. These rescaled results allow relative comparisons and it can be concluded that

- Previous results confirm our conclusion that there is no significant difference between noise annoyance caused by TGV and maglev trains.
- Although Neugebauer et al. found a significant annoyance difference between conventional IC and maglev trains, this difference is smaller than the data spread in our results. This may be caused by differences in study design, the selection of subjects and/or by the more limited range of sounds used by Neugebauer et al.
- The annoyance found by Vos (2004) for conventional IC trains, is indeed relatively lower than the annoyance found in our experiment and the experiment by Neugebauer et al. This may be caused by these sets of trains' different sound exposures. The different selection of the subjects may have led to a reduced spread. However, the experimental setup likewise may have contributed to this lower annoyance ratings.

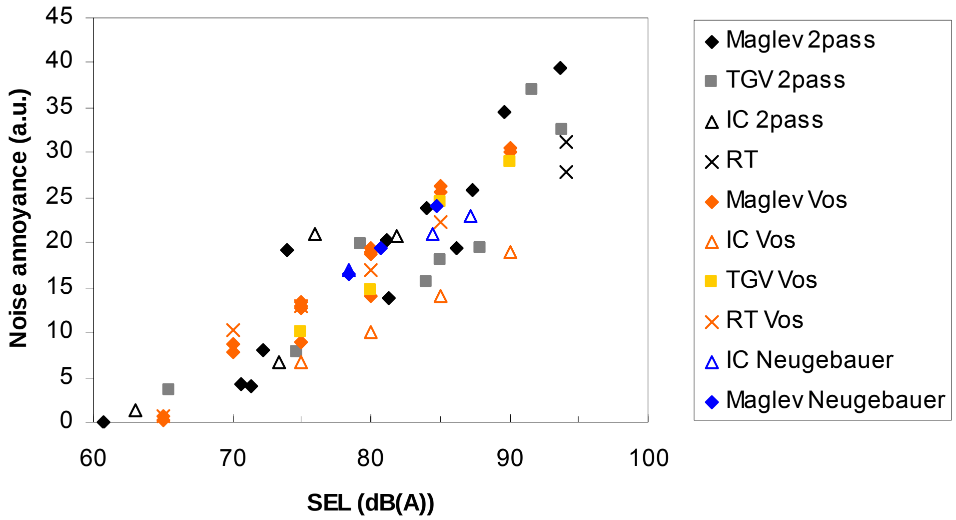

Figure 45. Noise annoyance found in different experiments as a function of SEL in dB(A). Scale units of annoyance matched to produce similar pschoacoustical functions for maglev noise; thus only relative comparisons are allowed.

10. References

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Appendix A
questionnaire items for selection of participants

Part 1

A1_1	How often do you hear noises	(6 items; 0-6 scale)
A1_2	Annoyed last 12 months	(6 items;0-10 scale)
A1_3	Sleep disturbed last 12 months	(6 items, 0-10 scale)
A2	Type of living environment	(9 items; y/n alt)
A3_2	Frequency of feeling afraid in situations	(1 item; 0-10 scale +1)
A4_1	Quality of own neighborhood	(9 items; 0-10 scale +2)
A4_2	Total quality of the emission in neighborhood	(1 item, 0-10 scale +1)
A4_3	Satisfaction with living situation	(1 items; 0-10 scale +2)
A5_1	Type of house you live in	(8 items; y/n)
A5_2	Own/rented/etc home	(4 items; y/n)
A5_3	Age	(1 item; free response)
A5_4	Gender	(1 item; 2 alternatives)
A5_5	Civil status	(5 items, y/n)
A5_6	Members of family	(7 items; y/n)
A5_7	Level of education	(10 items; y/n)
A5_8	Type of work/study/unempl./handicapped/etc.	(10 items, y/n)

A1 to A5: all questions from

EAM Franssen, JEF van Dongen, JMH Ruysbroek, H Vos, RK Stellato. Hinder door milieufactoren en de beoordeling van de leefomgeving in Nederland. Inventarisatie verstoringen 2003. RIVM rapport 815120001 / 2004 + TNO rapport 2004-34.

Part 2

B1	Reason to complain about environ. factors	(8 items, 1-4 scale +1)
B2	Worried about environ. factors	(14 items; 1-4 scale +1)
B3_1	Environ. factors affecting your health in future	(8 items; 1-3 scale +1)
B3_2	Environ. factors affecting your quality of life	(8 items; 1-3 scale +1)
B4*	Opinions of environment	(4 items; select one!)
B5_1	How sensitive to weather changes	(1 item; 0-10 scale +1)
B5_2	How sensitive to noise	(1 item; 0-10 scale +1)
B5_3	How sensitive to air pollution	(1 item; 0-10 scale +1)
B6_1	How is your health in general	(1 item; y/n +1)
B6_2	Long standing illness or health problem	(1 item; y/n +1)
B6_3	Activity restriction due to health problems	(1 item; 1-3 scale +1)
B7_1	Last month, felt happy	(1 item; 1-6 scale +1)
B7_2	Last month, felt miserable	(1 item; 1-6 scale +1)
B7_3	Last month, tired	(1 item; 1-6 scale +1)
B8_1	Hearing problem	(1 item; y/n)
B8_2	Diagnosed hearing impairment	(1 item, y/n)
B8_3	Do you have hearing aid	(1 item; y/n)

B1 to B3: from SN 4201 - Eurobarometer 51.1 : Environmental Issues and Consumer Associations, April-May, 1999. Codebook INRA (EUROPE) - 51.1 - Spring 1999.

Exception: B3_2: new analog item construction to include “quality of life” concept

*B4 was omitted from the final questionnaire based on RIVM expert advice

B5: General sensitivity scales towards environmental factors (used in various noise and health surveys)

B6: Special Eurobarometer 183-7 / Wave 58.2: The health of adults in the European Union. European Opinion Research Group EEIG, December 2003, Brussels.

B7: Eurobarometer 58.2: The mental health status of the european population. European Opinion Research Group EEIG, April 2003, Brussels.

B8: General survey questions on hearing ability: from Hyena airport study (courtesy of Dr Wolfgang Babisch)

Appendix B
Questionnaire used for recruiting potential panellists

Gent, 16 november 2004

Beste mevrouw, meneer, bewoners van dit huis,

In opdracht van het Ministerie Verkeer en Waterstaat, Directoraat-Generaal Personenvervoer, voert een Europees team van universiteiten een onderzoek uit naar de ervaring van geluidshinder. Voor dit onderzoek zijn wij op zoek naar een aantal vrijwilligers. Het experiment waaraan deze vrijwilligers zullen deelnemen bestaat uit het beoordelen van de invloed van lawaai tijdens het relaxen. Tijdens het experiment zullen de deelnemers enkele eenvoudige vragen over hun ervaring beantwoorden. Het experiment zal plaatsvinden in een vakantiewoning in **Westkapelle** en ongeveer **4 uur** duren. De geselecteerde deelnemers zullen na afloop van het experiment een vergoeding van **100 euro** ontvangen.

De selectie van de deelnemers voor dit experiment gebeurt op basis van de vragenlijst die u hierna vindt. We willen daarom graag aan een van de bewoners van dit huis, ouder dan 21 jaar, vragen om onderstaande vragenlijst in te vullen en terug te sturen in de bijgesloten envelop. U hoeft hierop geen postzegel te plakken. Invullen van de vragenlijst duurt ongeveer 10 minuten. Het is essentieel dat degene die de vragenlijst invult ook degene is die aan het experiment in de woning in Westkapelle zal deelnemen. Ook als u niet wenst deel te nemen, zouden we het zeer op prijs stellen als u de vragenlijst ingevuld terugstuurt en de reden opgeeft waarom u niet wenst deel te nemen.

Bij dit onderzoek wordt gehouden aan de Nederlandse Wet Bescherming Persoonsgegevens. Dit betekent dat de gegevens uit uw vragenlijst anoniem worden verwerkt en uw privacy ten allen tijde gewaarborgd blijft. Indien u geselecteerd wordt voor het experiment, nemen wij telefonisch contact met u op om een afspraak te maken.

Mocht u nog vragen hebben over dit onderzoek, dan kunt u ons altijd bellen op het nummer 0032 9 264 9970 (Universiteit Gent, België).

Met vriendelijke groeten,

Prof. Dick Botteldooren

Universiteit Gent, België

Vragenlijst

In onderstaande vragenlijst vindt u een aantal ☐ die u door aanvinken of inkleuren kan selecteren. Bij de vragen waar u met een getal moet op antwoorden is een hokje voorzien. Het is belangrijk dat u alle vragen nauwkeurig invult, indien u wenst dat we u als kandidaat voor deelname aan het experiment kunnen selecteren.

Om een fout te verbeteren trekt u gewoon een lange schuine streep door het foutief ingevulde hokje.

Vraag 1 **(A5_1)**

In wat voor huis woont u?

Flat of etagewoning (beneden) ☐
Flat of etagewoning (hogere verdieping) ☐
Tussenwoning in een rij ☐
Hoekwoning in een rij ☐
Twee onder één kap ☐
Vrijstaand ☐
Anders ☐
Weet niet/wil niet zeggen ☐

Vraag 2 **(A5_2)**

Is dit huis een:

Huurhuis ☐
'Eigen huis' (koophuis) ☐
Anders ☐
Weet niet/wil niet zeggen ☐

Vraag 3 **(A5_3)**

Uw leeftijd :

Vraag 4 **(A5_4)**

Uw geslacht:

man ☐ vrouw ☐

Vraag 5 **(A5_5)**

Wat is uw burgerlijke staat?

Gehuwd of duurzaam samenwonend ◙
Eén ouder gezin met kinderen ◙
Alleenstaand ◙
Thuiswonend bij ouders ◙
Weet niet/wil niet zeggen ◙

Vraag 6 **(A5_6)**

Hoeveel leden telt uw huishouden, inclusief uzelf? ☐, waarvan ☐ jonger dan 15 jaar

Vraag 7 **(A5_7)**

Wat is de hoogste opleiding die u heeft afgemaakt? (s.v.p. slechts één antwoord aankruisen)

Geen opleiding ◙
Lagere school ◙
Lager beroepsonderwijs (bijv LTS, huishoudschool) ◙
MAVO (of Mulo) ◙
Middelbaar beroepsonderwijs ◙
HAVO/VWO (of HBS/Gymnasium/MMS) ◙
Hoger beroepsonderwijs ◙
Wetenschappelijk onderwijs (universiteit) ◙
Anders ◙
Weet niet/wil niet zeggen ◙

Vraag 8 **(A5_8)**

Welke omschrijving is op u het meest van toepassing?

Ik werk betaald, 32 uur of meer per week ☐
Ik werk betaald tussen 19 en 32 uur per week ☐
Ik werk betaald, minder dan 19 uur per week ☐
Ik ben fulltime thuis ☐
Ik ben gepensioneerd/in de VUT ☐
Ik volg onderwijs/studeer ☐
Ik doe vrijwilligerswerk ☐
Ik ben werkloos/werkzoekend ☐
Ik ben invalide/arbeidsongeschikt ☐
Weet niet/wil niet zeggen ☐

Vraag 9 **(B8_1)**

Om dit experiment te kunnen uitvoeren is het noodzakelijk dat de deelnemers voldoende goed horen. Met onderstaande vragen wordt gepeild naar uw gehoor. Na het experiment zal een gehoortest uitgevoerd worden om de kwaliteit van uw gehoor objectief vast te stellen.

Denkt u dat u gehoorproblemen heeft?

Ja ☐ Neen ☐

Vraag 10 **(B8_2)**

Heeft uw dokter ooit een verminderde gehoorfunctie bij u vastgesteld?

Ja ☐ Neen ☐

Vraag 11 **(B8_3)**

Draagt u een gehoorapparaat?

Ja ☐ Neen ☐

Vraag 12 **(A1_1)**

De volgende vragen betreffen uw ervaringen over langere tijd, te weten over de afgelopen 12 maanden (of zoveel korter als u hier woont). Het gaat niet om een enkel incident, maar om de situatie zoals die in het algemeen is. Wilt u de vragen steeds beantwoorden voor de situatie zoals die bij u thuis is. Het gaat er niet om of u geluiden hoort waar u werkt, of als u ergens anders bent, maar echt bij u in huis, voor de deur, in uw tuin of op uw balkon.

Hoe vaak heeft u de afgelopen 12 maanden bij u thuis (in en om uw woning) geluid gehoord van:

	Dagelijks	Minstens 1x per week	Minstens 1x per maand	Minstens 1x in het afgelopen jaar	Niet in het afgelopen jaar (nooit)	Weet niet
Verkeer van een weg met een snelheidsbeperking tot 30-50 km per uur (dus binnen de bebouwde kom)	☐	☐	☐	☐	☐	☐
Verkeer van een weg met een snelheidsbeperking tot 80 km per uur (bijv. een provinciale weg)	☐	☐	☐	☐	☐	☐
Verkeer van een snelweg met een snelheidsbeperking tot 100-120 km per uur	☐	☐	☐	☐	☐	☐
Treinen	☐	☐	☐	☐	☐	☐
Passagiers- en vrachtvliegtuigen	☐	☐	☐	☐	☐	☐
Geluiden vanuit de buurwoning	☐	☐	☐	☐	☐	☐

Vraag 13 **(A1_2)**

In welke mate vond u het geluid van ... in en om uw woning over de laatste 12 maanden hinderlijk of niet hinderlijk? U kunt dit aangeven met een cijfer waarbij 0 staat voor ‘helemaal niet hinderlijk’ en 10 staat voor ‘heel erg hinderlijk’?

(u hoeft de vraag enkel te beantwoorden voor geluidsbronnen die u soms hoort)

	0=helemaal niet hinderlijk									10=heel erg hinderlijk
	0	1	2	3	4	5	6	7	8	9	10
Verkeer van een weg met een snelheidsbeperking tot 30-50 km per uur (dus binnen de bebouwde kom)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verkeer van een weg met een snelheidsbeperking tot 80 km per uur (bijv. een provinciale weg)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verkeer van een snelweg met een snelheidsbeperking tot 100-120 km per uur	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Treinen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Passagiers- en vrachtvliegtuigen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Geluiden vanuit de buurwoning	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 14 **(A1_3)**

In welke mate werd uw **slaap** over de laatste 12 maanden verstoord of niet verstoord door:

(U hoeft de vraag enkel te beantwoorden voor geluidsbronnen die u soms hoort)

	0=helemaal niet verstoord							10=heel erg verstoord			
	0	1	2	3	4	5	6	7	8	9	10
Verkeer van een weg met een snelheidsbeperking tot 30-50 km per uur (dus binnen de bebouwde kom)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verkeer van een weg met een snelheidsbeperking tot 80 km per uur (bijv. een provinciale weg)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verkeer van een snelweg met een snelheidsbeperking tot 100-120 km per uur	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Treinen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Passagiers- en vrachtvliegtuigen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Geluiden vanuit de buurwoning	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 15 **(A2)**

Welke situaties lijken op uw eigen woonsituatie? (meerdere antwoorden mogelijk)

Wonen in een drukke straat	☐
Wonen in een polder onder zee- of rivierniveau	☐
Wonen in een landbouw of bollenteelt gebied	☐
Wonen onder de aanvliegroute van een groot vliegveld	☐
Wonen langs een spoorlijn	☐
Wonen in de buurt van een groot vliegveld	☐
Wonen in de buurt van (petro)chemische industrie	☐
Wonen langs een route voor gevaarlijke stoffen	☐
Geen van deze	☐

Vraag 16 **(A4_1)**

De volgende vragen gaan over de buurt waarin u woont. Ik wil u nu vragen om uw buurt te beoordelen. Kunt u uw buurt op de volgende aspecten, zoals die de afgelopen 12 maanden waren, beoordelen?

Hoe beoordeelt u de/het …… in uw buurt? (nvt = niet van toepassing; wn = weet niet)

0 = zeer slecht 10 = uitmuntend

	0	1	2	3	4	5	6	7	8	9	10	nvt	wn
Verkeersveiligheid	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sociale veiligheid (criminaliteit)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Geur	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Fabrieksgeluid	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Verkeersgeluid (weg- en railverkeer en vliegtuigen)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kwaliteit van de bodem (bodemverontreiniging)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stofneerslag van industrie	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kwaliteit van het water in singels, sloten en kanalen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Zwerfvuil	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 17 **(A4_2)**

Als u nu een cijfer zou moeten geven voor de totale milieukwaliteit (dus lucht, geluid, water en bodem tezamen) in deze buurt, welk cijfer is dat dan?

U kunt dit aangeven met een cijfer waarbij 0 staat voor ‘zeer slecht’ en 10 staat voor ‘uitmuntend’. U kunt natuurlijk ook een cijfer daartussen in kiezen. (wn = weet niet)

0 = zeer slecht 10 = uitmuntend

0	1	2	3	4	5	6	7	8	9	10	wn
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 18 **(A4_3)**

We willen u nu iets vragen over uw tevredenheid met een aantal andere aspecten van uw woonsituatie. In hoeverre bent u tevreden of ontevreden over de volgende aspecten van het wonen hier? (nvt = niet van toepassing; wn = weet niet)

0 = helemaal niet tevreden 10 = zeer tevreden

	0	1	2	3	4	5	6	7	8	9	10	nvt	wn
Uw woning	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Onderhoud van de buurt (schoonhouden, ophalen van huisvuil en weghalen van zwerfvuil)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ruimte in de buurt voor speelgelegenheid e.d.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dichtheid van de bebouwing (hoeveelheid huizen per gebied)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
De mensen in de buurt (levendigheid, bekenden, vriendelijkheid, gezelligheid)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
De milieusituatie (mate van hinder door geluid-/stank/trillingen/stof van bedrijven, verkeer e.d.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
De voorzieningen in de buurt (winkels, scholen, café's e.d.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Groenvoorzieningen in de omgeving (parken, sportvelden e.d.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Het openbaar vervoer (naar werk, voorzieningen in de stad, recreatiegebieden e.d.)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Onderhoud van gebouwen en wegen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
De parkeergelegenheden	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 19 **(B1)**

Heeft u, waar u leeft, zeer veel, tamelijk veel, niet heel veel of geen reden tot klagen over … ?

	Zeer veel	Tamelijk veel	Niet veel	Geen	Weet niet
De kwaliteit van het leidingwater	☐	☐	☐	☐	☐
Lawaai	☐	☐	☐	☐	☐
Luchtverontreiniging	☐	☐	☐	☐	☐
Afvalverwijdering	☐	☐	☐	☐	☐
Gebrek aan groene ruimte	☐	☐	☐	☐	☐
Schade aan het landschap	☐	☐	☐	☐	☐
Verkeersdrukte	☐	☐	☐	☐	☐

Vraag 20 **(B2)**

Als u denkt aan Nederland, bent u erg bezorgd, enigszins bezorgd, niet erg bezorgd, helemaal niet bezorgd over … ?

	Erg bezorgd	Enigszins bezorgd	Niet erg bezorgd	Helemaal niet bezorgd	Weet niet
Verontreiniging van rivieren en meren	☐	☐	☐	☐	☐
Verontreiniging van de zee en de kust	☐	☐	☐	☐	☐
Schade aan dieren, planten en habitats	☐	☐	☐	☐	☐
Luchtverontreiniging	☐	☐	☐	☐	☐
Verontreiniging door landbouw (insekticide, herbicide, enz.)	☐	☐	☐	☐	☐
Industrieel afval	☐	☐	☐	☐	☐
De ontwikkeling van biotechnologie	☐	☐	☐	☐	☐
Produktie van nucleaire energie	☐	☐	☐	☐	☐
Motorsport in landelijke omgeving zoals motorboten, bijeenkomsten van motorrijders, alle terrein voertuigen, enz.	☐	☐	☐	☐	☐
Stadsproblemen (verkeer, lawaai, verontreiniging)	☐	☐	☐	☐	☐
De risico's van industriële activiteiten	☐	☐	☐	☐	☐
Natuurrampen zoals overstromingen, stormen, aardbevingen, etc.	☐	☐	☐	☐	☐

Vraag 21 **(B5_1)**

Wilt u in de volgende vragen uw antwoord aangeven met een cijfer van 0 t/m 10, waarbij 0 'helemaal niet gevoelig' betekent en 10 'zeer gevoelig'.

In welke mate bent u gevoelig voor **het weer**?

0 = helemaal niet gevoelig 10 = zeer gevoelig

0	1	2	3	4	5	6	7	8	9	10	wn
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 22 **(B5_2)**

In welke mate bent u gevoelig voor **geluiden**?

0 = helemaal niet gevoelig 10 = zeer gevoelig

0	1	2	3	4	5	6	7	8	9	10	wn
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 23 **(B5_3)**

In welke mate bent u gevoelig voor **luchtverontreiniging**?

0 = helemaal niet gevoelig 10 = zeer gevoelig

0	1	2	3	4	5	6	7	8	9	10	wn
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 24 **(B3_1)**

In welke mate kunnen, volgens u, de volgende zaken uw gezondheid in de toekomst beïnvloeden?

	Helemaal niet	Een beetje	Heel sterk	Weet niet
Luchtkwaliteit	☐	☐	☐	☐
Waterkwaliteit	☐	☐	☐	☐
Lawaai	☐	☐	☐	☐
Afval	☐	☐	☐	☐
Kwaliteit van het voedsel	☐	☐	☐	☐
Chemicaliën	☐	☐	☐	☐
Bouwmaterialen	☐	☐	☐	☐
Klimaatsverandering	☐	☐	☐	☐

Vraag 25 **(B3_2)**

In welke mate kunnen, volgens u, de volgende zaken de kwaliteit van uw leven in de toekomst beïnvloeden?

	Helemaal niet	Een beetje	Heel sterk	Weet niet
Luchtkwaliteit	☐	☐	☐	☐
Waterkwaliteit	☐	☐	☐	☐
Lawaai	☐	☐	☐	☐
Afval	☐	☐	☐	☐
Kwaliteit van het voedsel	☐	☐	☐	☐
Chemicaliën	☐	☐	☐	☐
Bouwmaterialen	☐	☐	☐	☐
Klimaatsverandering	☐	☐	☐	☐

Vraag 26 **(B6_1)**

Hoe is uw algemene gezondheidstoestand?

Zeer goed	Goed	Tamelijk	Slecht	Zeer slecht	Weet niet
☐	☐	☐	☐	☐	☐

Vraag 27 **(B6_2)**

Lijdt u aan een langdurige ziekte of aandoening (gezondheidsprobleem)?

Ja	Neen	Weet niet
☐	☐	☐

Vraag 28 **(B6_3)**

Bent u, vanwege een gezondheidsprobleem, sinds 6 maanden of langer beperkt geweest in activiteiten die mensen gewoonlijk doen?

Ja, ernstig beperkt	Ja, enigszins beperkt	Neen, niet beperkt	Weet niet
☐	☐	☐	☐

Vraag 29 **(A3_2)**

Sommige mensen zijn angstiger dan anderen. Hoe vaak komt het voor dat u zich in een situatie bevindt waarin u zich angstig voelt? Wilt u dit aangeven met een cijfer van 0 t/m 10, waarbij 0 'helemaal nooit' betekent en 10 'zeer vaak'.

0 = helemaal nooit 10 = zeer vaak

0	1	2	3	4	5	6	7	8	9	10	wn
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Vraag 30 **(B7_1)**

Heeft u zich tijdens de voorbije maand **gelukkig** gevoeld?

De hele tijd	Heel dikwijls	Dikwijls	Zelden	Zeer zelden	Nooit	Weet niet (meer)
☐	☐	☐	☐	☐	☐	☐

Vraag 31 **(B7_2)**

Heeft u zich tijdens de voorbije maand **gedeprimeerd of ellendig** gevoeld?

De hele tijd	Heel dikwijls	Dikwijls	Zelden	Zeer zelden	Nooit	Weet niet (meer)
☐	☐	☐	☐	☐	☐	☐

Vraag 32 **(B7_3)**

Heeft u zich tijdens de voorbije maand **moe en loom** gevoeld?

De hele tijd	Heel dikwijls	Dikwijls	Zelden	Zeer zelden	Nooit	Weet niet (meer)
☐	☐	☐	☐	☐	☐	☐

Deelname aan het experiment

◘ Ja, ik wens deel te nemen aan het experiment

Tijdens de periode tussen 21 november en 10 december 2004, ben ik doorgaans vrij op:

	Morgen	Namiddag	Avond
Weekdagen			
Weekend			

◘ Neen, ik wens niet deel te nemen omdat ....

Uw naam: ....

Uw adres: ....

....

Telefoonnummer waar u overdag bereikbaar bent: ....

Mobiel: ....

Ik heb deze vragenlijst waarheidsgetrouw ingevuld en geef toestemming om de gegevens die hierin vermeld zijn te gebruiken voor de selectie van proefpersonen gedurende de looptijd van dit project[1].

Datum:

Handtekening:

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[1] Na afloop van het project worden de persoonsgegevens (naam, adres en telefoonnummer) uit de databank verwijderd.

Appendix C
Instruction sheet magnitude scaling

Instructies

Tijdens het experiment zullen wij u vragen in welke mate u gehinderd wordt door het verkeersgeluid dat u het tijdens het relaxen hoort.

Wij geven u eerst enkele instructies over hoe u te werk moet gaan bij het rapporteren van de mate waarin u gehinderd wordt.

U maakt een beoordeling door een getal toe te kennen dat volgens u het best overeenstemt met de mate waarin u gehinderd wordt door verkeersgeluid. U gebruikt hiervoor de getallen waar u zich het best bij voelt. Het is echter belangrijk dat de relatie tussen de getallen die u kiest overeenstemt met de relatie tussen de mate waarin u zich gehinderd voelt door de verschillende geluiden. Dit betekent dat, als u een verkeersgeluid dubbel zo hinderlijk vindt dan een ander verkeersgeluid, u aan het meest hinderlijke verkeersgeluid een getal toekent dat 2 keer groter is dan het getal dat u toekende aan het minder hinderlijke verkeersgeluid. Bent u *helemaal niet gehinderd*, bijvoorbeeld omdat u geen geluid hoorde, dan kent u steeds de waarde 0 toe.

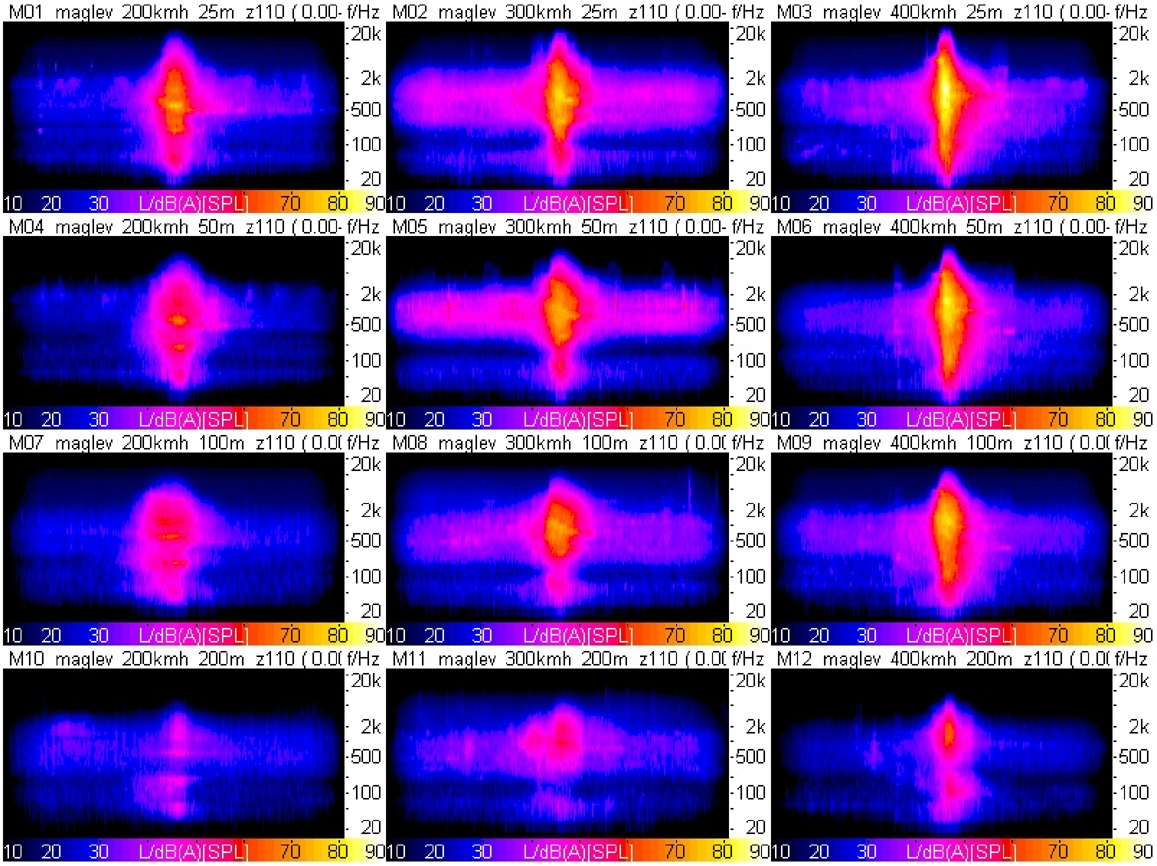
Er zijn geen juiste of onjuiste antwoorden. Wij zijn alleen geïnteresseerd in “hoe” hinderlijk u de verkeersgeluiden ervaart. Tracht zo spontaan mogelijk te antwoorden en volg uw eigen intuïtie.

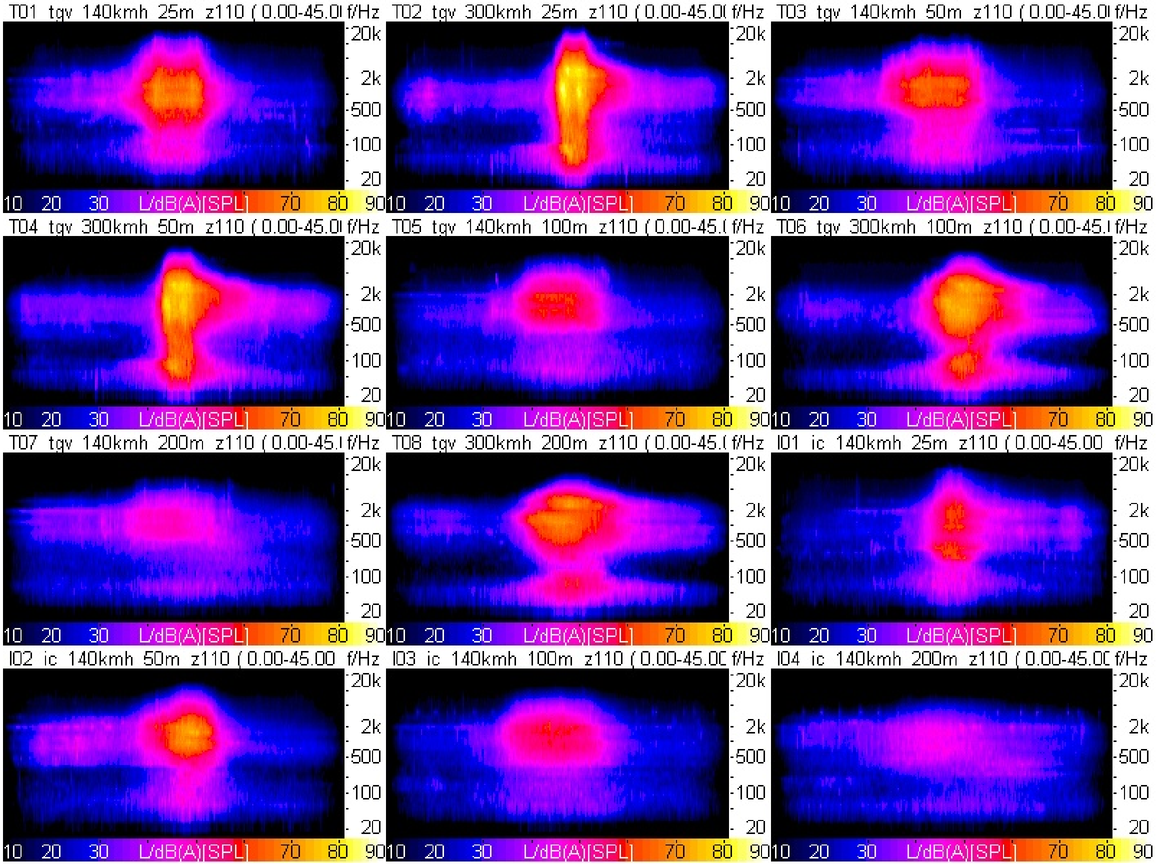
Nu volgt er een voorbeeld. Indien u aan het eerste verkeersgeluid een getal 60 toekent en u vindt het volgende verkeersgeluid dubbel zo hinderlijk, dan moet u hieraan 120 toekennen. Indien een derde verkeersgeluid half zo hinderlijk is, dan kent u hieraan de waarde 30 toe, enz.

Heeft u nog vragen?

Dan gaan we nu van start met een oefensessie.

Appendix D


M01 maglev 200kmh 25m z110 (0.00-
M02 maglev 300kmh 25m z110 (0.00-
M03 maglev 400kmh 25m z110 (0.00-
M04 maglev 200kmh 50m z110 (0.00-
M05 maglev 300kmh 50m z110 (0.00-
M06 maglev 400kmh 50m z110 (0.00-
M07 maglev 200kmh 100m z110 (0.0
M08 maglev 300kmh 100m z110 (0.0
M09 maglev 400kmh 100m z110 (0.0
M10 maglev 200kmh 200m z110 (0.0
M11 maglev 300kmh 200m z110 (0.0
M12 maglev 400kmh 200m z110 (0.0
f/Hz
20k
2k
500
100
20
10 20 30 L/dB(A)[SPL] 70 80 90


T01 tgv 140kmh 25m z110 (0.00-45.0
T02 tgv 300kmh 25m z110 (0.00-45.0
T03 tgv 140kmh 50m z110 (0.00-45.0
T04 tgv 300kmh 50m z110 (0.00-45.0
T05 tgv 140kmh 100m z110 (0.00-45.
T06 tgv 300kmh 100m z110 (0.00-45.
T07 tgv 140kmh 200m z110 (0.00-45.
T08 tgv 300kmh 200m z110 (0.00-45.
I01 ic 140kmh 25m z110 (0.00-45.00
I02 ic 140kmh 50m z110 (0.00-45.00
I03 ic 140kmh 100m z110 (0.00-45.0
I04 ic 140kmh 200m z110 (0.00-45.0
f/Hz
20k
2k
500
100
20
10 20 30 L/dB(A)[SPL] 70 80 90