Audio-visual listening test of moderators for perception of road noise

Milestone 2.2 in the FAMOS project

FAMOS
a CEDR project

FORCE TECHNOLOGY

LÄRMKONTOR GmbH

SINTEF

TECHNICAL NOTE

Audio-visual listening test of moderators for perception of road noise

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Performed for CEDR, Conference of European Directors of Roads

Project no.: 119-35797

TC-101736

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OVERVIEW

Title	Audio-visual listening test of moderators for perception of road noise
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Summary

This report has been produced as a part of the FAMOS project, FActors MOderating people's Subjective reactions to road noise. The project is financed by the Conference of European Road Directors (CEDR).

The purpose of FAMOS is to quantify how non-acoustic factors (i.e. non L_{den}-based factors) modify people's subjective reactions to road traffic noise. Audio-visual listening tests were tested as a mean to quantify the effect of such factors. The main purpose for performing listening tests in this project was to investigate the possibility for using this as a tool for measuring the effect of moderators in specific scenarios.

The listening tests were performed with 24 listeners for 10 scenarios recorded in positions near busy roads with various conditions for vegetation, traffic visibility and types of noise screens. Combinations of noise played back over a stereo setup and video recordings on a screen were shown to assessors, in FORCE Technology's listening room. Videoclips for all ten positions were shown together with the same neutral excerpt of road noise played back at play back levels of 45, 50,…75 dB(A).

Results obtained in a laboratory setting will probably deviate from the results obtained in larger scale field studies, such as socio-acoustic surveys. The hypothesis was, that relative changes between alternative stimuli will change the response in the same way as in real life, even if the size of the effect may differ.

The positions for the video recordings for the listening tests were selected so that there were variations in the moderators of interest, i.e.: the visibility of the traffic and the amount of greenery (trees, bushes and grass) and the type and appearance of the noise screens. But there were also variations regarding traffic flow, traffic intensity, distance to the road and speed limits.

For all positions a significant increase of the annoyance with the noise level increase was found. The annoyance response was higher and steeper than the "Miedema"-curve found from surveys. That was to be expected, as the stimuli, the context and the attention to the noise was more uniform in the listening test than in larger scale field studies where the moderators may vary between the respondents.

In general, we found that the annoyance increased if the fit between video and sound was assessed to be bad. Our hypothesis is, that if you expect a rather silent environment and are exposed to higher noise levels than expected, the noise is perceived as more annoying. This could also be seen as, when the expectations are not fulfilled, the annoyance increases.

Multiple regression analysis has been performed to find the influence of the moderators Greenery and Visible traffic. The variables were the percentage of the area of greenery measured in the video pictures and the percentage of visible traffic estimated from inspection of the video images.

For the audio-visual listening tests, we can conclude:

- We have found dose response curves with a high degree of explanation of the variation of the annoyance response ($R^2 > 0.95$).
- There is a significant influence of the visual impact on the assessment of the annoyance. Differences in the annoyance corresponded to level differences up to 4 dB for the same sound stimuli.
- The influence of the moderators Greenery and Visible Traffic on annoyance is significant but opposite findings in practice and in the literature. The hypothesis is that this is caused by disappointed expectations from what is seen on the videos.
- If audio-visual listening tests are used for this purpose, it is important that they are realistic and give a good understanding of the full context.

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1 Preface

This report has been produced as a part of the FAMOS project. FAMOS responds to the questions of the Conference of European Road Directors (CEDR) call in 2018 on Noise and Nuisance: Psycho-Acoustics: Improved Understanding of People's Subjective Reactions to Road Noise.

WHO has estimated that about 1.2 million healthy life-years are lost annually in Europe due to road traffic noise. About half of these can be related to the subjective element: annoyance. This is a huge challenge for the National Road Administrations. Analyses of results from noise surveys reveal that only about 1/3 of the variance in the annoyance response is caused by the noise level itself, whereas the other 2/3 are determined by so-called non-acoustic factors. This means that the annoyance response can be altered within wide limits without doing any changes to the actual noise level. So when road administrations have used all the technically feasible and economically possible measures, the noise impact can still be reduced by making changes in the non-acoustic factors known to moderate the annoyance response.

The objective of FAMOS is to quantify how different factors modify people's subjective reactions to road traffic noise. The project uses scientific methods to find, extract and analyze data from existing annoyance surveys. The most promising findings will be tested experimentally by the use of questionnaire studies, listening testing in the laboratory and soundscape measurements/sound walks. The results will be used to develop a handbook on how "moderators" can be used by road administrations to reduce noise annoyance.

FAMOS is the acronym for "FActors MOderating people's Subjective reactions to road noise". The project is carried out over two years and started in December 2019. The project consortium consists of three partners:

- FORCE Technology in Denmark (Project leader)
- LÄRMKONTOR in Germany
- SINTEF in Norway

The report has been produced within Work Package WP 2 of the project, which deals with "Analysing data and hypotheses testing" and is led by the FORCE. This report presents the results of a series of listening tests performed to investigate moderators related to presence of greenery as well as visibility of the road/traffic. The importance of these two moderators were among others highlighted in the international literature study performed in WP1 of the FAMOS project. The report is produced by Torben Holm Pedersen from FORCE as milestone M.2.2 of the FAMOS project. The report has quality control been reviewed by Hans Bendtsen and Christer Volk from FORCE as well as Truls Gjestland from SINTEF. The CEDR Transnational Road Research Programme funded by Belgium – Wallonia, Denmark, Ireland, Netherlands, Norway, Sweden and United Kingdom has financed the FAMOS project.

2 Introduction

2.1 Background

This report has been produced as a part of the FAMOS project. FAMOS responds to the questions of the Conference of European Road Directors (CEDR) call in 2018 on Noise and Nuisance: Psychoacoustics: Improved Understanding of People's Subjective Reactions to Road Noise.

The annoyance from road traffic noise is a challenge for the National Road Administrations. Only a part of the variance in the annoyance response is directly related to the noise level, and the rest determined by factors not related to the noise exposure. This means that the noise annoyance may be lowered without doing any changes to the actual noise exposure when the influence of these non-acoustic factors is known.

The purpose of FAMOS is to quantify how different factors modify people's subjective reactions to road traffic noise. Listening tests was to be tested as a mean to quantify the effect of non-acoustic factors in Work Package 2. Therefore, listening tests were performed with stimuli from alternative locations with different conditions with regard to selected moderators.

This report presents the testing of listening tests with focus on moderators related to visual appearance of the road and its immediate surroundings. Listening tests were performed in the laboratory at alternative locations with three different conditions with regard the selected moderators:

1. Presence of vegetation or greenery situated between and near the road and the people exposed to the noise.
2. Visibility of road and traffic for the people exposed to the noise.
3. Visibility of different types of noise screening.

2.2 Audio-visual Listening test

Listening tests are performed to investigate the perception of sounds by humans. During the listening test the listeners, the assessors, characterises the sound in a number of objectively defined perceptual attributes or they may characterize their own feelings about the sound, i.e. an affective assessment, e.g. the annoyance of the sound. In both cases the answers from a number of assessors will be the basis for mean values and confidence intervals for the attributes tested. Especially for the affective tests the context of the sound and the listening situation usually have a significant impact on the results. Therefore, results obtained in a laboratory setting will probably deviate from the results obtained in real life e.g. obtained by socio-acoustic surveys.

To improve the realism of the laboratory test in this project, we have performed the test as audio-visual listening tests (AV listening tests) by combining the sounds with video recordings of the relevant scenarios. Furthermore, the assessors were instructed to imagine a specific context situation during their assessments.

The hypothesis is that relative changes between alternative stimuli in an AV listening test will change the response in the same way as in real life, even if the size of the effect may differ.

2.3 Purpose

The main purpose for performing listening tests in this project is to investigate the possibility for using this as a tool for measuring the effect of moderators in specific scenarios in future projects conducted by national road administrations.

If the effect of moderators can be quantified with this method, the results will be taken into account, when merging findings in other parts of the FAMOS project.

3 The locations

The location for the video and sound recordings for the listening tests were selected so that there were variations in the moderators of interest, i.e.: the visibility of the traffic and the amount of greenery (trees, bushes and grass) and the type and appearance of the noise screens. The positions were chosen at major roads and motorways in and around Copenhagen.

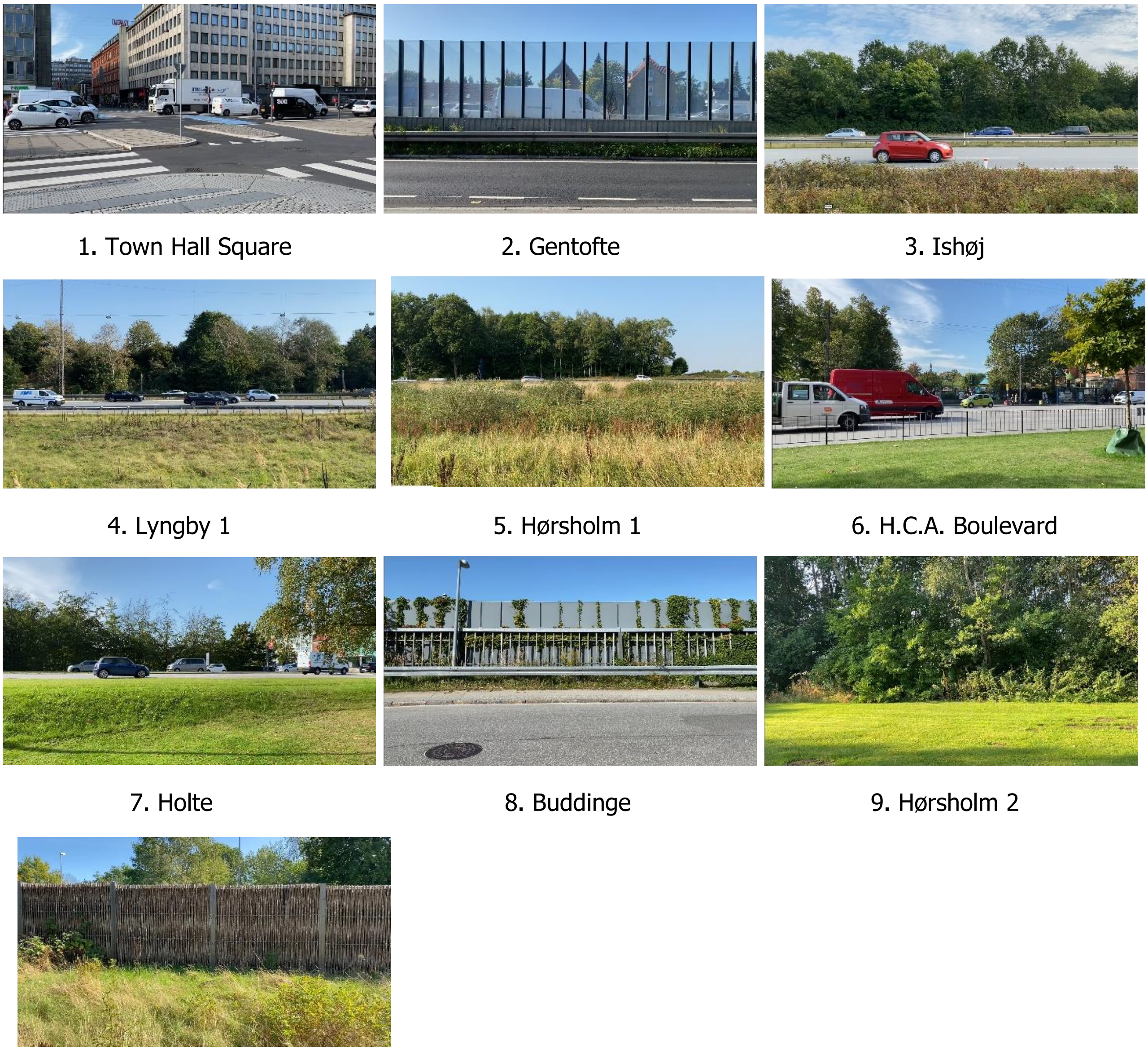
3.1 Overview

An overview of the positions is given in Table 1 and in Figure 1.

Positions	Type	Traffic Visible, %	Greenery, %	Screen	Approx. distance to road, m
1. Town Hall Square	Major road	100	0	No	15
2. Gentofte	Motorway	80	17	Glass	20
3. Ishøj	Motorway	100	63	No	15
4. Lyngby 1	Motorway	100	67	No	25
5. Hørsholm 1	Motorway	50	77	No	70
6. H.C.A. Boulevard	Major road	100	57	No	10
7. Holte	Major road	100	78	No	20
8. Buddinge	Motorway	0	22	Steel	(20)
9. Hørsholm 2	Motorway	0	100	No	(50)
10. Lyngby 2	Motorway	0	59	Wood	(15)

Table 1 *The positions for video and sound recordings to the listening tests.*

The percentage of greenery is calculated as the area of the video image occupied by vegetation. The calculation is approximate and is based on the area of 2-5 rectangles fitted to the greenery in the video pictures for each location.



1. Town Hall Square
2. Gentofte
3. Ishøj
4. Lyngby 1
5. Hørsholm 1
6. H.C.A. Boulevard
7. Holte
8. Buddinge
9. Hørsholm 2
10. Lyngby 2

Figure 1 *Overview over the recording positions, the visual stimuli.*

3.2 Positions for recordings

Position 1 – Town Hall Square

This position is at the corner if the Town Hall Square. The road, the same as in position 6, is one of the busiest roads in the central Copenhagen with four lanes in each direction. There are road crossings and traffic lights at and to both sides 100-200 meters from the measuring position. Speed limit 50 km/h.

Figure 2 *Position 1. Picture taken from the video shown at the listening test.*
Distance to road: 15 m. 0 % greenery.

Position 2 – Gentofte

The Elsinore motorway E47, north of Copenhagen, in Gentofte with 3 lanes in each direction. The traffic is seen through a transparent glass screen, but the lower part of the vehicles is hidden by the low concrete barrier. It is estimated that the traffic is 80 % visible. A little greenery is seen in front of the glass screen and between the houses on the opposite side of the motorway. Speed limit 90 km/h.

Figure 3 *Position 2. Picture taken from the video shown at the listening test.*
Distance to road: 20 m. 17 % greenery.

Position 3 – Ishøj

Køge Bugt Motorvejen, E47, west of Copenhagen, in Ishøj with 3 lanes in each direction. The traffic is fully visible. There is greenery both in front and behind the motorway. Speed limit 110 km/h.

Figure 4 *Position 3. Picture taken from the video shown at the listening test. Distance to road: 15 m. 63 % greenery.*

Position 4 – Lyngby 1

The Elsinore motorway E47, north of Copenhagen, three lanes in each direction, near the Danish Technical University, DTU. Traffic fully visible and greenery both in front and behind the road. Speed limit 90 km/h.

Figure 5 *Position 4. Picture taken from the video shown at the listening test. Distance to road: 25 m. 67 % greenery.*

Position 5 – Hørsholm 1

The Elsinore motorway E47, north of Copenhagen with two lanes in each direction, near Hørsholm. The traffic is partly hidden by greenery, 50 % visible. Greenery both in front and behind the road. Speed limit 110 km/h.

Figure 6 *Position 5. Picture taken from the video shown at the listening test. Distance to road: 60 m. 77% greenery. Traffic 50 % visible.*

Position 6 – H.C. Andersens Boulevard

This position was close to the Town Hall. The road, the same as in position 1, is one of the busiest roads in the central Copenhagen with four lanes in each direction. There are road crossings with traffic lights to both sides some hundred meters from the measuring position. The traffic is fully visible and there is greenery both in from and behind the road except for the utmost right corner. Speed limit 50 km/h.

Figure 7 *Position 6. Picture taken from the video shown at the listening test. Distance to road: 10 m. 57 % greenery.*

Position 7 – Holte

Major road with 4 lanes near the Holte town hall. The traffic is fully visible and there is greenery both in front and behind the road except at the utmost right. Speed limit 50 km/h.

Figure 8 *Position 7. Picture taken from the video shown at the listening test. Distance to road: 20 m. 78 % greenery.*

Position 8 – Buddinge

The Ring Motorway M3 around Copenhagen with three lanes in each direction, in Buddinge. The traffic is hidden by a steel barrier, which is partly covered by greenery. Speed limit 110 km/h.

Figure 9 *Position 8. Picture taken from the video shown at the listening test. Distance to road: 20 m. 22 % greenery.*

Position 9 – Hørsholm 2

The Elsinore motorway E47, north of Copenhagen with two lanes in each direction, in Hørsholm near the townhall. The traffic is totally hidden by greenery which fill the whole picture. Speed limit 110 km/h.

Figure 10 *Position 9. Picture taken from the video shown at the listening test. Distance to road: 50 m. 100 % greenery.*

Position 10 – Lyngby 2

The Elsinore motorway E47, north of Copenhagen, two south going lanes in Lyngby. The traffic is totally hidden by the wooden screen. Speed limit 90 km/h.

Figure 11 *Position 10. Picture taken from the video shown at the listening test. Distance to road: 15 m. 59 % greenery.*

4 Method

Video and calibrated sound recordings were made at ten positions near busy roads. The recordings represented variations in the noise levels, the visibility of the traffic, the amount of greenery and the types of noise screens. Combinations of noise played back over a stereo setup and video recordings on a screen were shown to assessors, who assessed the annoyance of the different situations.

The listening tests were performed according to the guideline [1], see under Noise and annoyance: https://forcetechnology.com/en/all-industry-facilities/senselab-listening-test-sensory-evaluation/knowledge-sharing.

4.1 Recordings

The recordings were made were made 18th to 29th of September 2020 in good dry weather conditions with moderate wind and with dry roads. The vegetation was still green.

The original video and sound recordings lasted around 10 minutes in each of the ten positions. From these recordings neutral 30 seconds excerpt without any characteristic vehicles (visual or sound) were selected for the test.

Equipment	Make	Type no.
iPhone cameras. 4k resolution, 30 and 60 fps.	Apple	11 Pro & 12 Pro
Acoustic calibrator	Brüel & Kjær	4230
Measuring microphones with wind screens, 2 pcs.	Brüel & Kjær	4165
Preamplifiers, 2 pcs.	Brüel & Kjær	2669
Microphone power supply	Brüel & Kjær	5935
Hard disk recorder	Sound Devices	744t
Closed monitor headphones	Sennheiser	HD 280 Pro

Table 2 *The equipment used for the video and sound recordings.*

The calibrated sound recordings with the measuring microphones was analysed with the NoiseLab noise analysis software.

Figure 12 *Photos of the measuring setup.*

4.2 Listening room and sound reproduction

The listening tests with stereo loudspeakers were performed in the listening room, of FORCE Technology, SenseLab.

Figure 13 *The SenseLab listening room at FORCE Technology. The sound is played from the stereo setup and the video is shown at the large screen. The projector for the video is outside the listening room. The PC-screen is for the user interface.*

In the listening room a 26-channel surround system is installed but only the two front stereo speakers were used for this test.

The listening room and the 26-channel loudspeaker system fulfils ITU-R BS.1116-3, [2], with respect to reverberation time, background noise level and frequency response of the loudspeakers.

The background noise levels (measured with a 1-inch microphone Brüel & Kjær type 4145) are:

- Background and inherent microphone noise: L_{Aeq} = 11 dB
- As above plus ventilation at 20 %: L_{Aeq} = 12 dB
- As above with all 26 loudspeakers on: L_{Aeq} = 19 dB.

The ITU-R BS.1116-3, [2], requirements to the speaker system are +/-3 dB in the frequency range 250-2000 Hz, widening to +3 to -7 dB at 50 Hz. The system is well within these tolerances down to 30 Hz.

The equipment used for the listening tests at FORCE SenseLab is listed in Table 3.

Apparatus	**Make**	**Model**	**Remarks**
PC	Lenovo	Custom	Placed in control room
Two loudspeakers	Genelec	8050A	Placed in listening room
Sound card	RME	MADIface XT	Placed in control room
Digital/Analog interface	RME	M-32 DA	Placed in control room
Graphic equalizer	t.c. electronic	EQ STATION	For calibrating speakers
Acoustic calibrator	Brüel & Kjær	Type 4230	Calibrated 28-06-2018
Dual microphone supply	Brüel & Kjær	Type 5935	Calibrated 09-10-2018
Measuring amplifier	Brüel & Kjær	Type 2610	Calibrated 06-12-2018
Sound level meter	NTI	Sound level meter: XL2, Preamp: MA220, Microphone: MC230	Calibrated 04-02-2019

Table 3 *Equipment used for the listening tests.*

The FORCE Technology SenseLabOnline software version 4.0.3 was used for stimulus randomization, play-back and collection of assessments in the listening test.

The sound pressure levels stated, are measured in the listening position without the listener present.

4.3 Assessors

In total 24 assessors participated in the listening test. The persons participating were ordinary persons (non-expert listeners) recruited from SenseLabs group of "consumers" via Facebook. The participants received a gift card to shops for their participation. The ages of the participants were between 21 and 66 years with a mean of 40 years with 10 male and 14 female listeners.

No assessors were excluded according to post-screening of the test results.

4.4 Instruction and attributes

The instruction to the test persons, the assessors, is shown in Appendix 1. They were asked to assess different examples of traffic noise from samples with both audio and video. They were informed that the road is always close by but in some cases the traffic is not visible.

The assessors should imagine that you were at home and that the situation is like in the video, all day.

They were asked to get used to the situation before making an assessment - preferably at least 10 seconds.

They were asked to assess the following two attributes:

- Annoyance: State how annoying you perceive the sound, considering that you have to be in this place for an hour. Annoyance: The sound is bothering or disturbing.
- Does the sound fit: Watch the video and indicate to what extent you think the sound fits.

The definitions of the attributes were shown to the participants, next to the answering scales.

There were labels next to the continuous answering scale. The labels for the annoyance scale were the ones defined in ISO/TS 15666, [3].

Figure 14 *User interface for the listening test and the answering scales used. Upper scale: Annoyance. The scale labels are: Not at all, Slightly, Moderately, Very and Extremely.*
Lower scale: Does "The sound fit" (to the place). The scale labels are: Very bad, Bad, Neutral, Good, Very good.

4.5 Test plan

The listening test was completed in two separate sessions.

In session A the videoclips for all ten positions were shown together with the same neutral excerpt of road noise played back at noise levels of 45, 50, 55, 60, 65, 70, and 75 dB(A).

This would make it possible to construct dose-response curves for each of the scenarios and would give data enough for multiple regression analysis.

In session B the videoclips from position 1 (Rådhuspladsen), 5 (Hørsholm 1) and 6 (H.C. Andersens Boul.) were shown with the original and synchronised sound recordings at levels of 50, 60 and 70 dB(A) besides in combination with the neutral excerpt at the same levels. The purpose of session B was to see if it makes a difference in the assessments if the sound is original and synchronised or just a neutral traffic noise. Due to technical problems with session B, these results are inconclusive and will not be reported.

5 Results

5.1 Attribute assessments

In this clause the mean results of the attribute assessments are shown. The data in the graphs are the mean values and 95 % confidence intervals of the assessment for all 24 participants in the listening test.

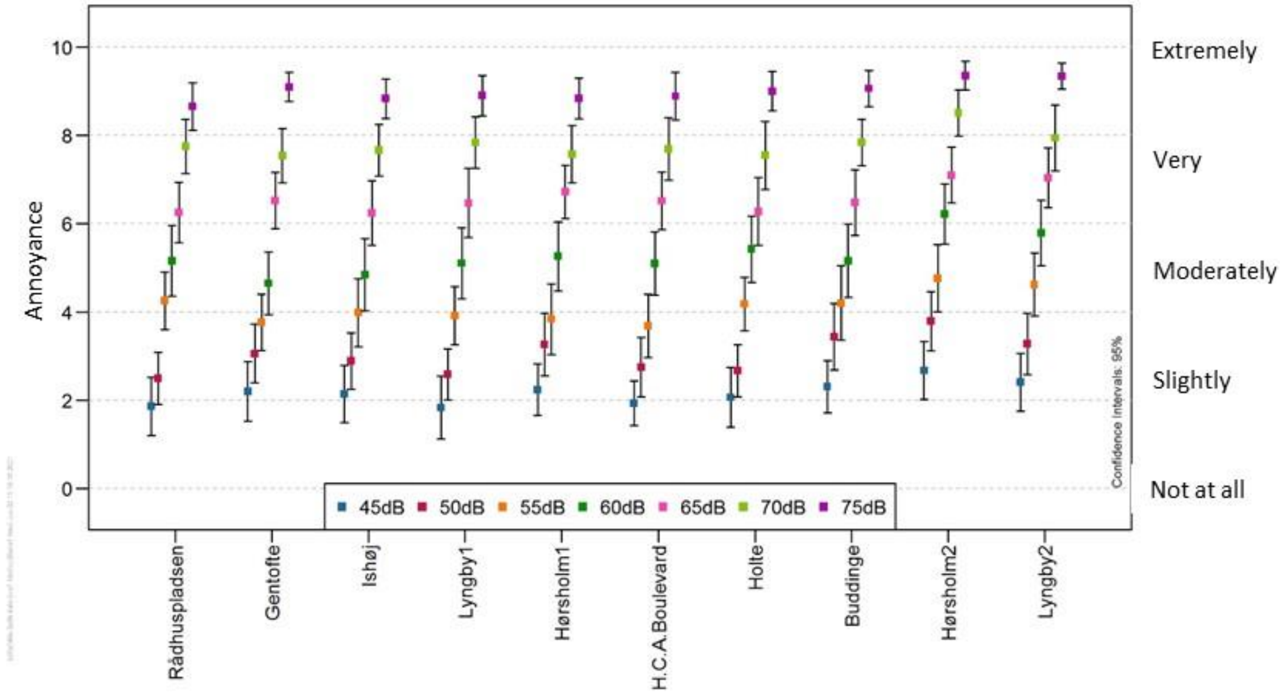


Figure 15 *Annoyance. Mean values and 95 % confidence intervals per position and per noise level (L_{Aeq}) The noise levels are L_{Aeq} for the sound samples.*

Figure 15 shows the assessments of annoyance. For all positions the annoyance increases with the noise level, but it can be seen that the annoyance for a specific noise level depends slightly on the position.

Figure 16 is a simplified version of Figure 15 where it is easier to follow the differences in annoyance between the positions for each of the noise levels. The middle levels have larger differences for positions 9 and 10 than the other levels.

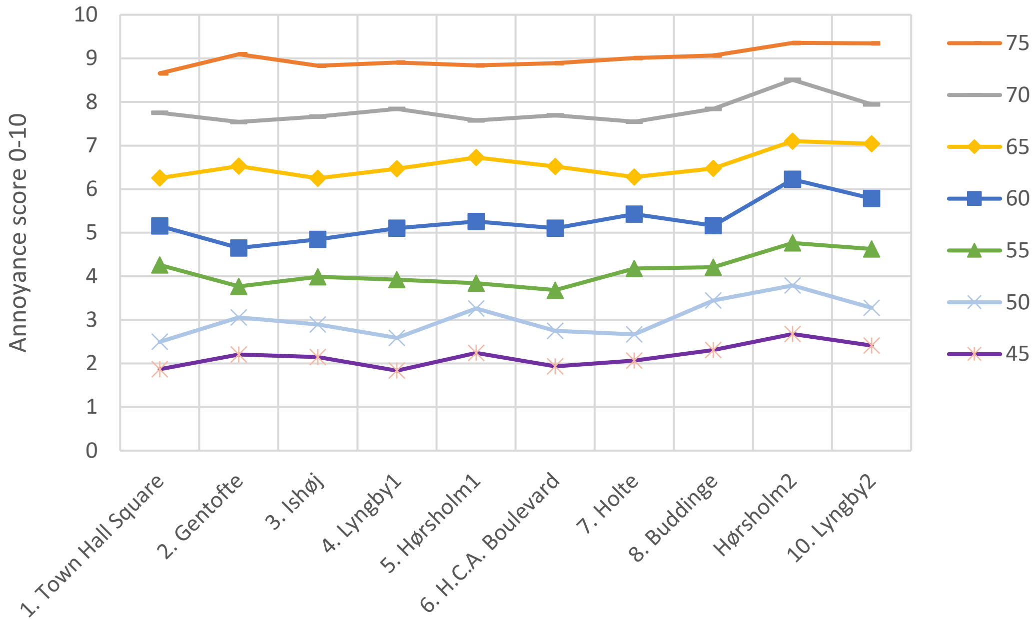


Figure 16 *Annoyance stated as annoyance score. A simplified version of Figure 15. The noise levels are L_{Aeq} for the sound samples.*

The average for all noise levels positions can be seen from Figure 17. There is a slight increase in the annoyance for positions 8. Buddinge, 9. Hørsholm 2 and 10. Lyngby 2.

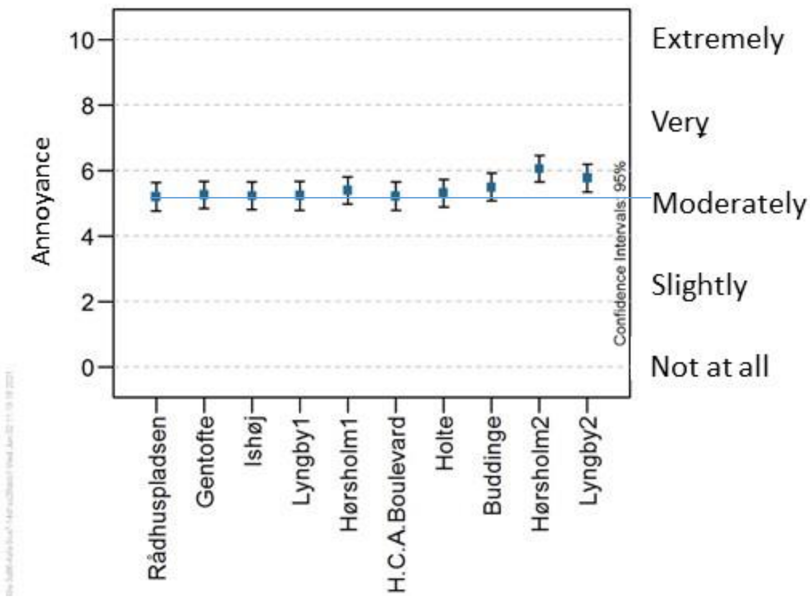


Figure 17 *Annoyance. Mean values and 95 % confidence over assessments for all noise levels per position.*

Figure 18 shows how the sound fits the video films. It is seen that the L_{Aeq}=75 dB is a bad fit for most positions. This can also be seen in Figure 19 where the fit in average for all positions is poor.

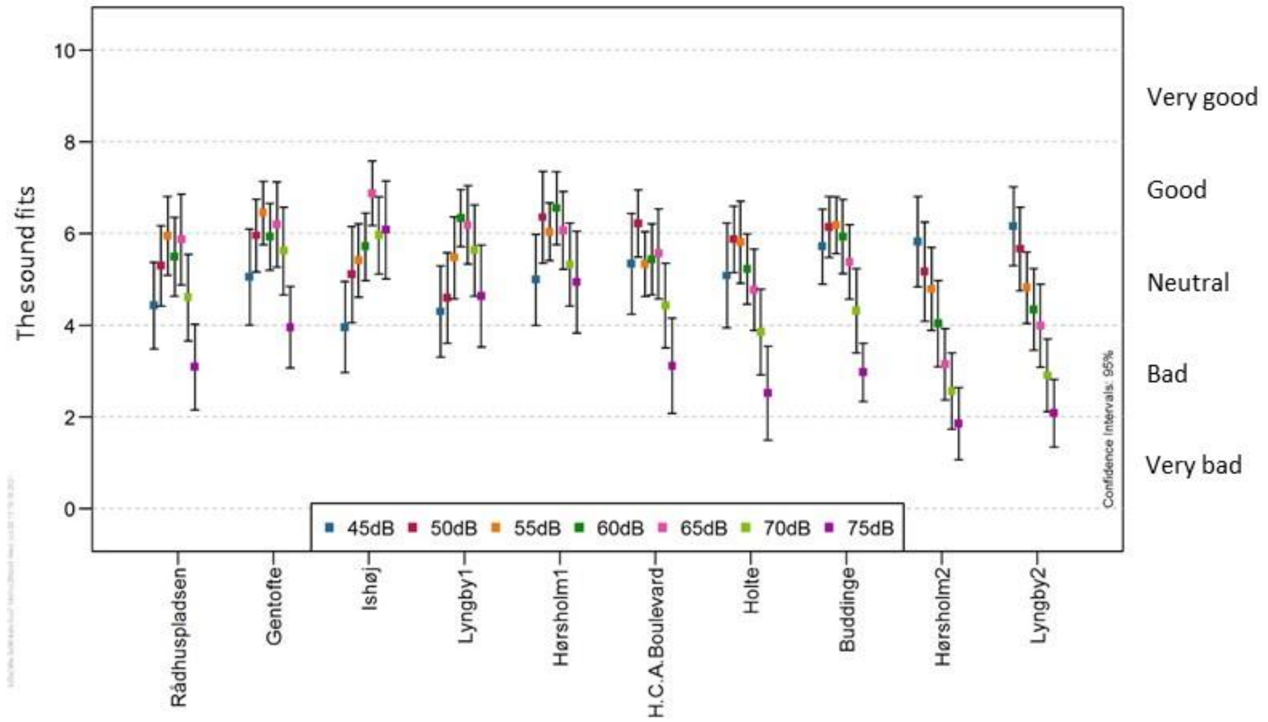


Figure 18 *The sound fits. Mean values and 95 % confidence over assessments for all noise levels per position. The noise levels are the L_{Aeq} for the sound samples.*

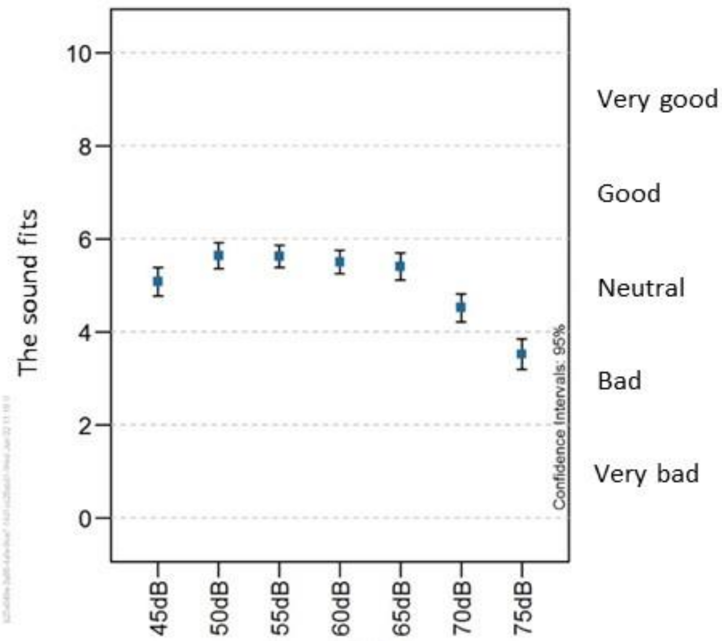


Figure 19 *The sound fits. Mean values and 95 % confidence over assessments for all positions. The noise levels are the L_{Aeq} for the sound samples.*

From Figure 18 it can be seen that for most positions the highest and the lowest levels are those with the poorest fit to the videos, but for positions Hørsholm2 and Lyngby 2 the best fit is obtained for the lowest levels. This also partly the case for Holte and Buddinge.

The real sound pressure levels (L_{Aeq}) in the measuring positions were in the range 60-70 dB with a few exceptions of up to 72 dB, so the 75 dB is higher than the noise levels in all positions. It was therefor decided to exclude the 75 dB level for the dose response analyses in next clause. In fact, as can be seen in Appendix 2, this also gave a slightly better fit to the data.

To conclude:

- For all positions there is a significant increase of the annoyance with the noise level.
- The fit between noise levels and videos were generally neutral to good, except for the highest levels which were bad.
- As the highest level, L_{Aeq}=75 dB, was higher than any of the real levels at the recording positions this level will be excluded in the analysis of the dose-response reactions.

5.2 Relations between the positions

From the assessments of the attributes, information about the positions can be deduced.

A principal component analysis, PCA, is a tool to get an overview over the many assessments of the attributes. PCA, is a dimensionality-reduction method that is often used to reduce the dimensionality of large data sets, by transforming a large set of variables into a smaller one that still contains most of the information in the large set. In this case we only have two dimensions: Annoyance and "The sound fits". According to the analysis (not shown) these two dimensions are almost perpendicular, i.e. independent.

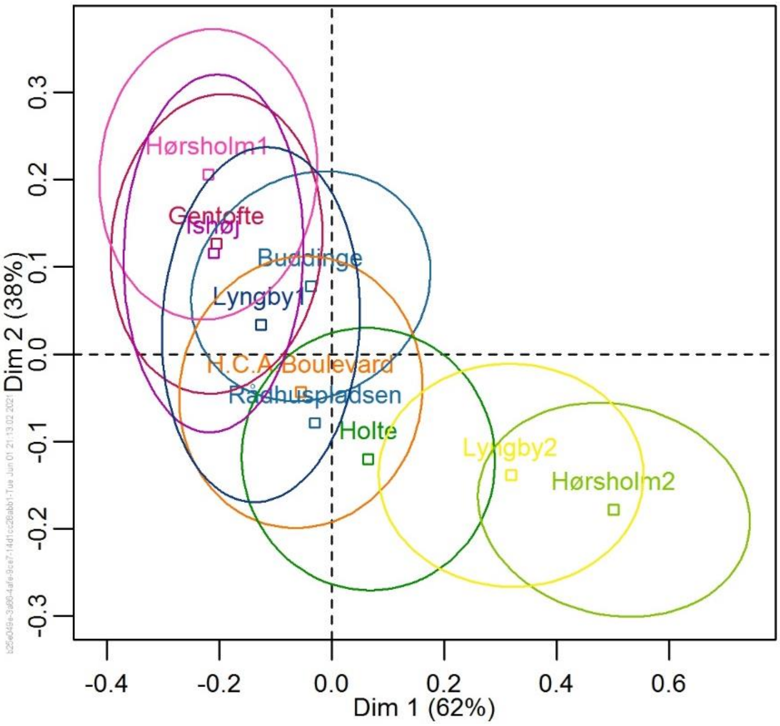


Figure 20 *A systems factor map from a principal component analysis (PCA) that show the mean values and confidence ellipses based on the assessments of the measuring positions of the two dimensions Annoyance (Dimension 1) and "The sound fits" (Dimension 2).*

From Figure 20 it is seen that the positions form a sort of curved diagonal in the diagram, with Lyngby2 and Hørsholm2 in the lower end and Hørsholm1, Gentofte and Ishøj at the upper end. The rest of the positions is in the middle part.

A cluster analysis based on the same data is shown in Figure 21. The longer the vertical bars are, the more different the clusters they connect are.

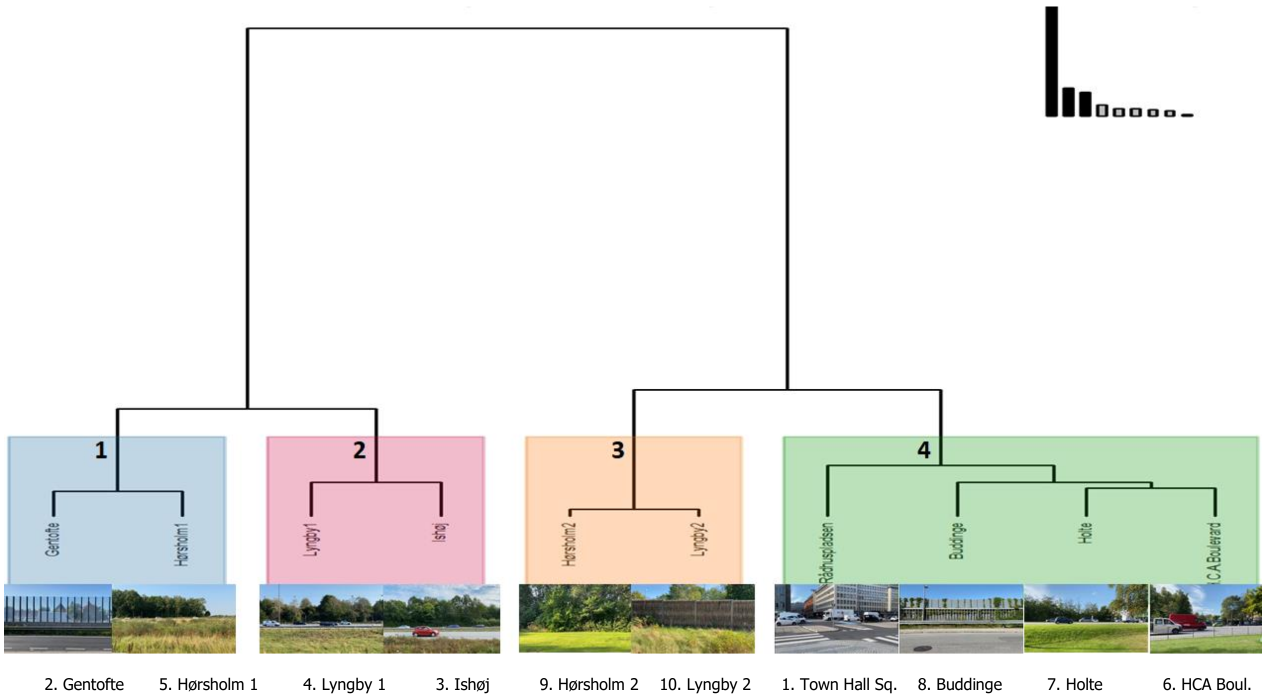


Figure 21 *A cluster analysis of the positions based on the assessments of Annoyance and "The sound fits".*

It is seen that in group 1 the traffic is partly hidden by a screen and vegetation. Group 2 is motorways with visible traffic and greenery. In Group 3 there is a lot of greenery and the traffic is not visible at all. Group 4 is the rest three positions with urban roads and slow traffic various amount of greenery and one position with a steel barrier.

6 Models for annoyance

6.1 Dose-response curves

The relation between the annoyance reaction and the noise exposure can be described with dose-response curves. Most often these curves represent the annoyance response as function of the noise exposure, L_{den}, where the annoyance responses are averaged over context, social and personal variables.

The responses are normally obtained from socio-acoustic surveys where hundreds to thousands of respondents are asked to assess the annoyance within the last year when they are at home. The annoyance assessment is meant to be the average over time and over the many situations where the annoyance is felt at home.

Although the annoyance measured in the listening test uses the same annoyance scale, the situation is quite different. It is a short-time assessment where the noise and video are more in focus than in the everyday life averaged over a year. Nevertheless, there may be similarities between the dose-response reactions and the non-acoustic factors that modifies the dose response curves.

With the purpose of finding the dose-response curves for the annoyance from traffic noise during the audio-visual listening test, the assessors were exposed for seven different noise levels in the range L_{Aeq} = 45-75 dB, for each video. As mentioned in clause 5.1, it was decided to exclude the L_{Aeq} = 75 dB level. From the assessments the annoyance as function of the corresponding L_{Aeq} levels can be found. The curves in Figure 22 shows a model with a logistic fit to the measured data. Detailed data for each of the positions can be found in Appendix 2.

It should be noted that normally the results from socio-acoustic surveys are given as curves showing the percentage of highly annoyed. For the listening tests we have chosen to show the results as the average annoyance response on the 0-10 scale.

The curve in Figure 22 can be described by the logistic function given by:

$$A = \frac{u}{1 + e^{-s(E-f)}}$$

where

- *A* is a measure for the annoyance response
- *u* is the **u**pper limit of *A (10 for the annoyance score, 100 for the percentage annoyed)*
- *s* is the **s**lope of the inverse logit function
- *E* is a measure for the noise **E**xposure e.g. L_{den}
- *f* is the value of E for a **f**ifty percent annoyance response

It is seen that the curve is defined by only two constants, the slope, s, and the fifty percent value of the exposure, f.

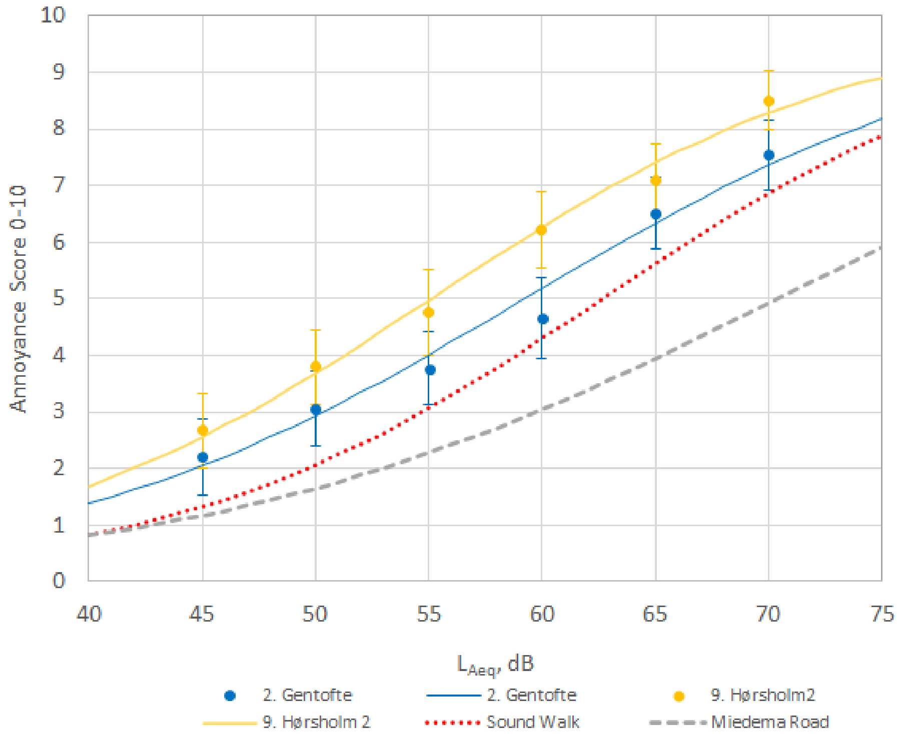


Figure 22 *Average annoyance response from the listening test for positions 2. Gentofte and 9. Hørsholm2. The vertical bars represent the 95 % confidence intervals. The red dotted curve is the annoyance found from sound walks [4] at the same locations. The grey dotted curve (Miedema road) is the average annoyance score deduced from [5] according to [6].*

The data for the curves in Figure 22 can be found in Table 4.

	2. Gentofte	9. Hørsholm 2	Sound Walk	Miedema Road
s	0.0950	0.1057	0.1064	0.0795
f	59.2	55.1	62.7	70.4

Table 4 *Data for s and f for the curves in Figure 22. See the formula on page 29.*

In Figure 22 data and curves for the locations with the highest (Hørsholm2) and lowest annoyance (Gentofte) are shown. As the confidence intervals are not or only slightly overlapping, we can state the difference between the two curves is significant. Also shown in the figure is the results from the sound walks performed at the same locations, [4].

The models from the listening test in Figure 22 gives good fit (R^2>0.97) to the data. It can be concluded that it is possible to find a dose-response curve from the listening test. Furthermore, it can be seen that there is a significant influence of the videos shown together with the noise. The influence corresponds to a level difference of up to 4 dB.

Compared to the corresponding curve from the sound walks at the same locations it can be seen that the annoyance is assessed higher in the listening tests.

For the Miedema data, the annoyance response is lower than the listening tests and the sound walks and with a less steep slope. This is to be expected because the survey data (the basis for the Miedema curve) is the average over all situations at home where the focus is not specifically at the traffic noise as in the listening tests and the sound walks.

In Figure 23 the dose-response curves for all the positions can be found.

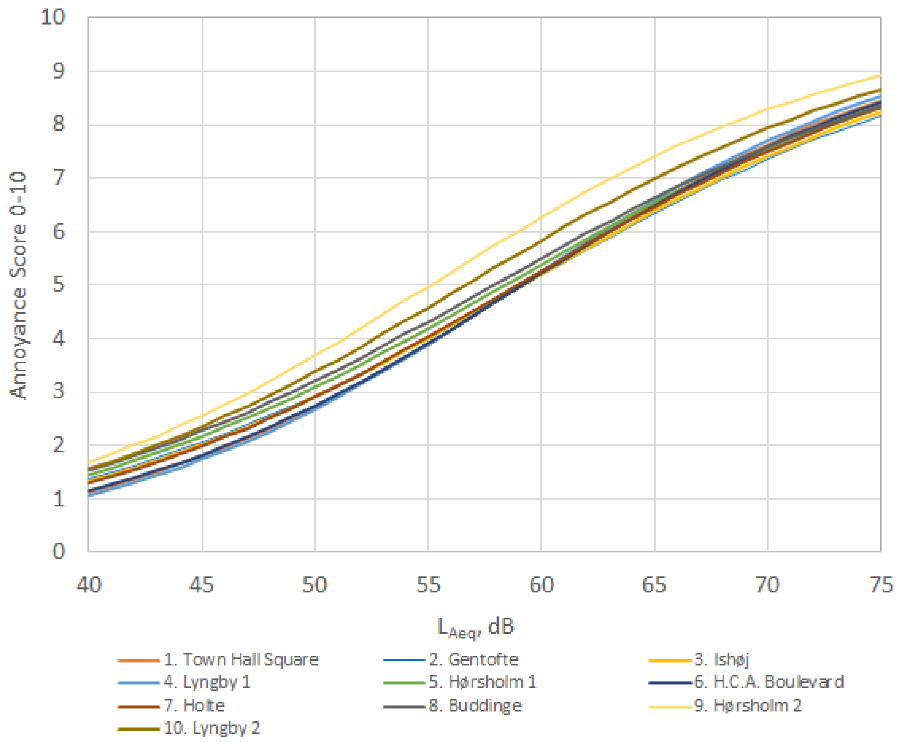


Figure 23 *Dose-response curves for each position modelled from the listening tests. The data behind the curves can be found in Appendix 2, Figure 27 together with the R^2 values. (all > 0.97). The curves that deviates most from the rest is Hørshom2 and Lyngby2.*

6.2 Influence of moderators

The next relevant topic is to see if the influence of non-acoustic factors can be modelled. Multiple regression analysis was made with all the factors from Table 1, but only the influence of greenery and the visibility of the traffic was found significant.

With the data from Table 1 and the response from the listeners a logistic regression model is made including L_{Aeq}, % greenery and % traffic visible.

According to the three-factor model, see Appendix 3, the annoyance found in the listening test can be calculated from:

*Annoyance = 10/(1+exp(-(0.1014*LAeq-0.2528*Visible%+0.1533*green%-5.829)))*

In Appendix 3 also the confidence intervals for the constants can be found. The influence of all the variables, L_{Aeq}, Visible Traffic% and Greenery% is significant.

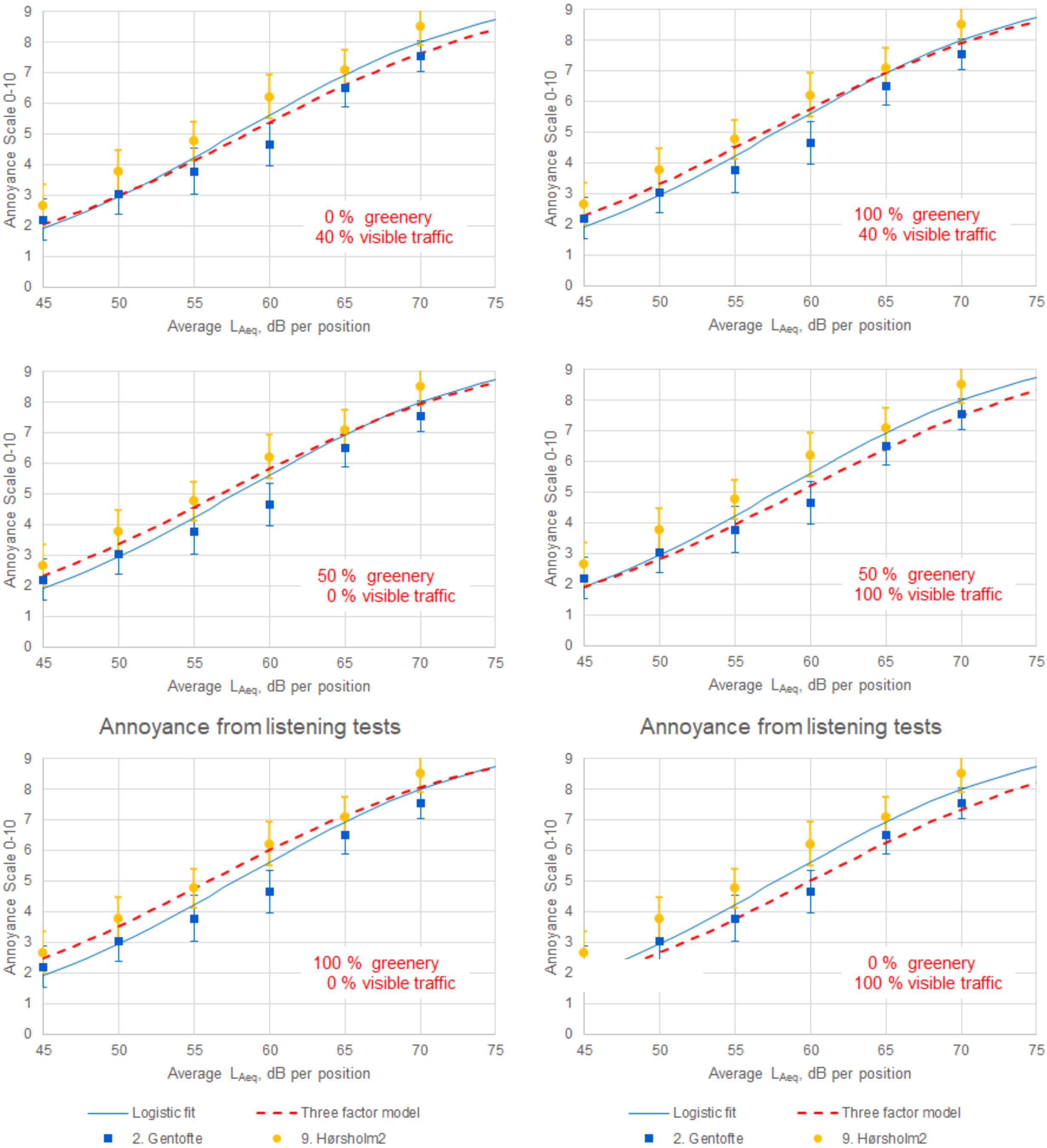


Figure 24 *The effect of greenery and visibility of the traffic on the dose-response curve (red dashed curve). The upper two graphs show the effect of greenery. The two middle graphs show the effect of visible traffic and the two lowest graphs show the maximum influence of greenery and visible traffic.*
The blue curve is a dose-response curve calculated with a model including only L_{Aeq}.
The influence of all the variables, L_{Aeq}, Visible Traffic% and Greenery% is significant. The data for Gentofte and Hørsholm2 are the same as in Figure 22.

The annoyance equivalent change in L_{Aeq} for 0-100 % greenery is 1.5 dB and for 0-100 % visual traffic the change is 2.5 dB. The maximum influence of the visual perception is approx. 4 dB.

Unfortunately, the sign of the constants are opposite other findings.

- The constant for visual traffic is negative, meaning that the more the traffic is seen the less is the annoyance. This is not in line with practical experience where the annoyance is less if the traffic cannot be seen, [7].
- The constant for greenery is positive, meaning more greenery is giving higher annoyance. This can in fact already be seen from Figure 15 and Figure 16 for the positions Hørsholm2 and Lyngby2 when comparing with the other positions. This is in contradiction with practical experience and findings in the literature, see e.g. [8] and [9].

We do not have any solid explanation to this, but we have the following hypothesis: When you are presented to a nice video with a lot of greenery and no visible traffic, as e.g. Figure 10, you will expect a rather silent environment. So, when you are exposed to higher noise levels than expected, the noise is perceived more annoying. Although the assessors were told that there was a road nearby in all positions, that information may not have been at the top of their mind when they made their assessments.

This hypothesis is supported by Figure 25. At all levels, except the two lowest, the trend is that the Annoyance increases when "The sound fits" decreases. This could also be seen as when the expectations are not fulfilled, the annoyance increases. This is also found in the Mini surveys from the FAMOS project [report to come later].

So, we conclude that it is important that the sound and the video fit each other and that the assessors have a full understanding of the context. This might be obtained e.g. by a short introductory tour in the video showing the road behind the screen or the greenery.

There were other differences in the positions than greenery and visible traffic, e.g. different speed of the traffic, traffic flow, road type, screen type and distance to the road. We have made a preliminary analysis of the three last-mentioned, but they were not found significant, maybe because of two few datapoints.

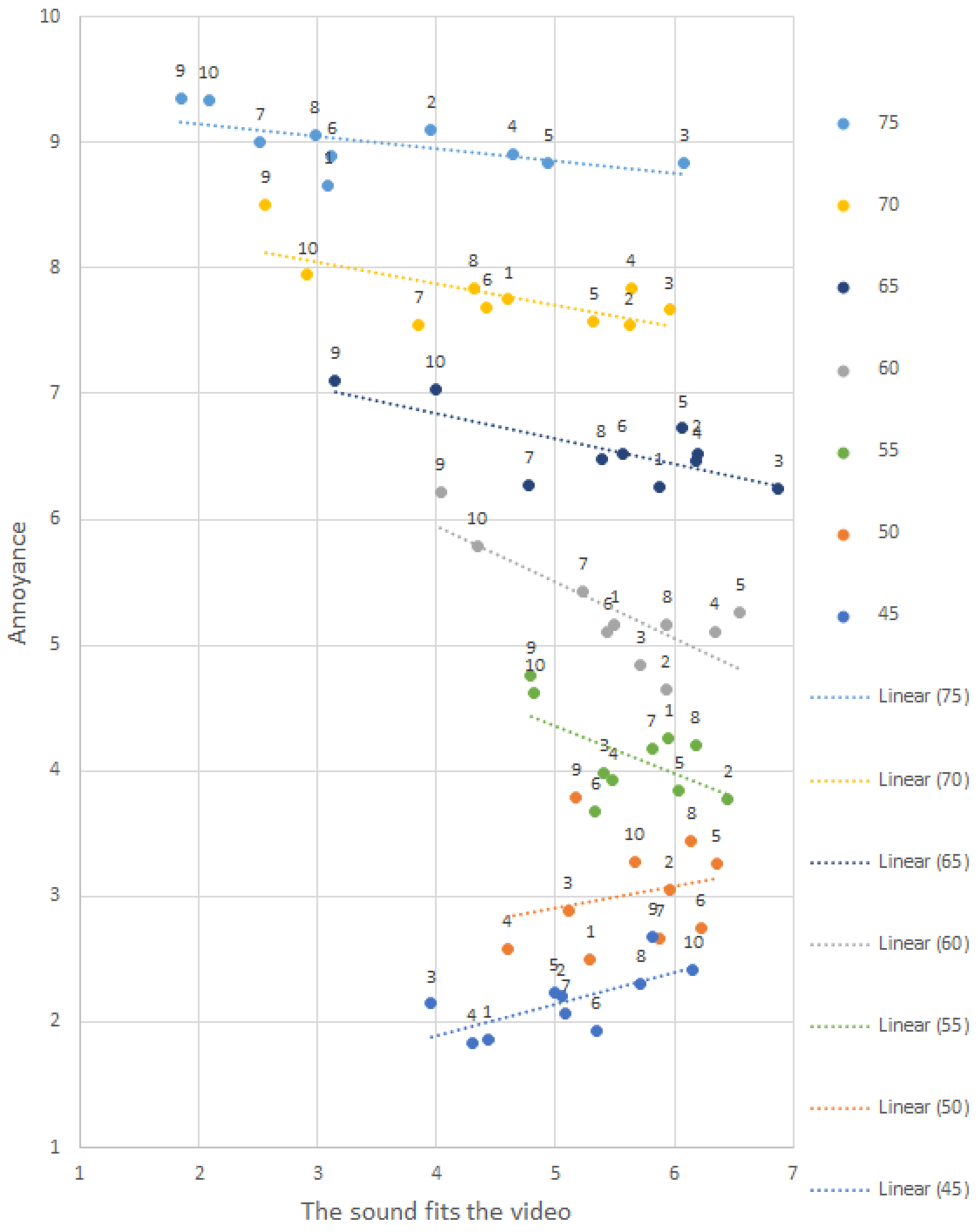


Figure 25 *The relation between "The sound fits" the video and the Annoyance 0-10 score. The colours indicate the levels and the numbers in the graph indicate the positions, see clause 3.*

7 Discussion and conclusions

The positions for the video recordings for the listening tests were selected so that there were variations in the moderators of interest, i.e.: the visibility of the traffic and the amount of greenery (trees, bushes and grass) and the type and appearance of the noise screens.

For all positions a significant increase of the annoyance with the noise level increasing was found. There were variations in this increase from the various positions.

The fit between noise levels and videos were generally neutral to good, except for the highest levels, which were the fit was assessed as bad. Furthermore, the highest level, L_{Aeq}=75 dB was higher than any of the real levels at the recording positions. Therefore, this level was excluded in the analysis of the dose-response reactions. Anyway, some of the remaining samples were assessed as having a bad fit to the video.

From the results on the annoyance assessments, logistic dose-response curves could be constructed with a good fit ($R^2 > 0.95$ on the mean values). The annoyance response was higher and steeper than the "Miedema" curve found from surveys. That was to be expected, as the stimuli, the context and the attention to the noise was more uniform in the listening test than in real life at home. The response was also higher than was found in the sound walks, [4].

The dose-response curves show that the visual perception has a clear and significant influence on the perception of annoyance from the noise. Differences in the annoyance corresponded to level differences, the annoyance equivalent change in noise levels, up to 4 dB for the same sound stimuli.

Multiple regression analysis has been performed to find the influence of the moderators Greenery and Visible traffic. The variables were the percentage of the area of greenery measured in the video pictures and the percentage of visible traffic estimated from inspection of the video images.

According to the analysis the annoyance increased with increasing percentage of greenery, which ins in contradiction to findings in practice and in the literature. Furthermore, the annoyance decreased with increasing visibility of the traffic. This is also in contradiction with other findings where the annoyance decreases when the traffic is not visible.

In general, we found that the annoyance increased with decreasing values of "The sound fits". So, our hypothesis is, that if you expect a rather silent environment and are exposed to higher noise levels than expected, the noise is perceived as more annoying. This could also be seen as, when the expectations are not fulfilled, the annoyance increases.

There were other differences in the positions than greenery and visible traffic, e.g. different speed of the traffic, traffic flow, road type, screen type and distance to the road. It is unknown whether that did influence the assessments of annoyance.

So, for the audio-visual listening test we can conclude:

- We have found dose response curves with a high degree of explanation of the variation of the annoyance response (R^2>0.95).
- There is a significant influence of the visual impact on the assessment of the annoyance.
- The influence of the moderators Greenery and Visible Traffic on annoyance is significant but opposite findings in practice and in the literature. The hypothesis is that this is caused by disappointed expectations from what is seen on the videos.
- If audio-visual listening tests are used for this purpose it is important that they are realistic and give a good understanding of the full context.

8 References

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Appendix 1 Test instruction in Danish language

Kære testperson

I denne test, skal du bedømme forskellige eksempler på trafikstøj ud fra en video med både lyd og billede.

I alle eksemplerne er vejen lige i nærheden, men i nogen tilfælde er trafikken ikke synlig.

Du skal forestille dig, at du er et bestemt sted hjemme, og at situationen er som i videoen, hele dagen.

Lyt til hvert scenarie længe nok til at du kan leve dig ind i situationen, inden du foretager en bedømmelse – gerne mindst 10 sekunder. Undlad at lytte mere end 30 sekunder (klippets længde), da du i så fald risikerer at løbe tør for tid.

Der er ingen rigtige eller forkerte svar, det er din egen opfattelse vi beder dig angive.

Definitioner ved skalaerne

Gene:

Angiv hvor generende du opfatter lyden, med tanke på at du skal være en times tid på dette sted

Gene: Lyden er irriterende eller forstyrrende.

Passer lyden:

Se på videoen og angiv i hvor høj grad du synes lyden passer.

Betjening:

Click på play-knappen for at starte lyd og billede. Giv din vurdering på skalaen, enten med piletaster, eller med musen.

Tryk på ”Next” for at gå videre til næste video/lydeksempel. Det er vigtigt at du *ser* på billedet, inden du foretager din vurdering. Det er ikke nok, kun at lytte til lyden.

Husk generelt at afspritte dine hænder, bære maske på gangarealer/reception, samt holde afstand til testinstruktør, og andre personer i FORCE Technology.

God fornøjelse med forsøget!

Appendix 2 Detailed test results

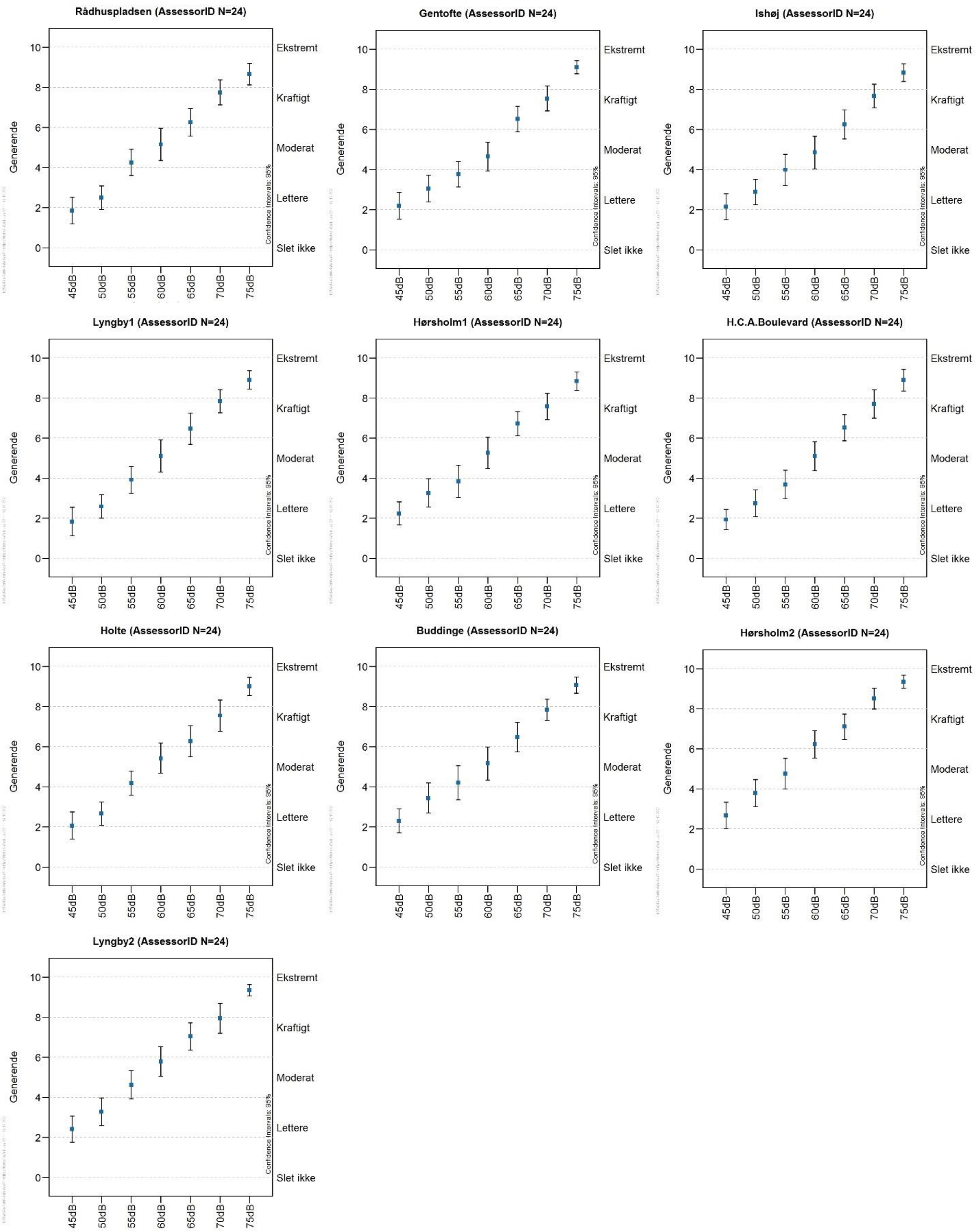

Figure 26 *Annoyance. Mean values and 95 % confidence intervals.*

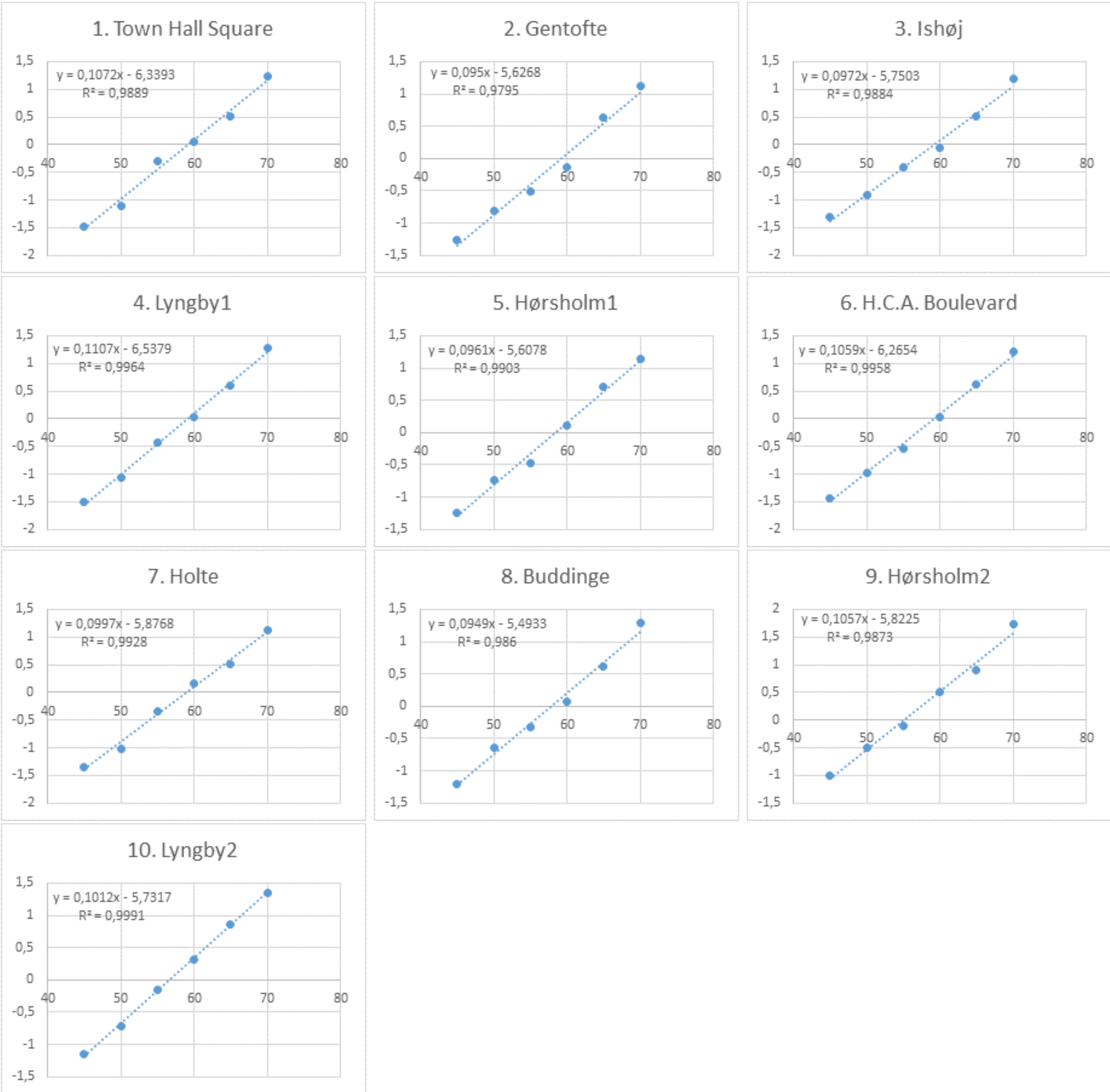

Figure 27 *The transformed mean assessments of annoyance, $T_A = LN(A/(10-A))$ where A is the annoyance. See [6] for a detailed explanations. The data for the noise level 75 dB are excluded from the analysis. It is seen that the transformed data has good linear fits with explained variance R^2 in the range 0.98-0.99 (with the 75 dB data the range is 0.95-0.99).*

Appendix 3 Models for annoyance

Table 5 shows different models for the logit transformed annoyance which is basis for the s-shaped dose-response curves, se clause 6.1. The influence of all the variables, L_{Aeq}, Visible Traffic% and Greenery% is significant. The model including these three variables is called the three factors model.

X: L_{Aeq}. Y: Annoyance — 70 data

R^2=0.96	*Coefficients*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-6.50312	1.86E-47	-6.84552	-6.16073
$L_{Aeq, dB}$	0.112574	6.44E-49	0.106945	0.118203

X: L_{Aeq}, Visible traffic%. Y: Annoyance — 70 data

R^2=0.98	*Coefficients*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-5.73433	4.02E-50	-5.95159	-5.51706
$L_{Aeq, dB}$	0.101362	2.6E-51	0.097706	0.105019
Visible T, %	-0.00271	2.92E-10	-0.00342	-0.002

X: L_{Aeq}, Greenery%. Y: Annoyance — 70 data

R^2=0.97	*Coefficients*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-6.02376	1.64E-44	-6.31172	-5.7358
$L_{Aeq, dB}$	0.101362	8.28E-45	0.096577	0.106148
Greenery, %	0.002196	0.002284	0.000819	0.003572

X: L_{Aeq}, Visible traffic%, Greenery%. Y: Annoyance — 70 data

R^2=0.98	*Coefficients*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-5.82875	1.77E-50	-6.04063	-5.61687
$L_{Aeq, dB}$	0.101362	2.62E-52	0.097949	0.104776
Visible T, %	-0.00253	5.29E-10	-0.0032	-0.00185
Greenery, %	0.001533	0.003212	0.000536	0.002531

X: L_{Aeq}, Visible traffic%, Greenery%. Y: Annoyance — 44 data

R^2=0.98	*Coefficients*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-5.83365	8.64E-35	-6.113	-5.55429
$L_{Aeq, dB}$	0.10063	1.17E-34	0.095773	0.105486
Visible T, %	-0.00197	0.000344	-0.00299	-0.00095
Greenery, %	0.001616	0.020028	0.000268	0.002965

Table 5 *Models for transformed annoyance, T_A (T_A =LN(A/(10-A)) where A is the annoyance~~.~~ (see [6] for a detailed explanations) with different combinations of the variables: L_{Aeq}, Visible Traffic% and Greenery%. The constants are valid when numbers for Greenery and Traffic visible is in the range 0-100. The last table is with 44 datapoints for "The sound fits" ≥ 5.*