UNIVERSITY OF TURKU

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TURKU UNIVERSITY OF APPLIED SCIENCES

SUBJECTIVE LISTENING EXPERIMENTS FOR ANNOYANCE INVESTIGATION

Presentation in Meluntorjuntapäivät 2023
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Noise and Annoyance – Why this work?

Noise = Non-desired sound

Non-desired + repetition in time ⇨ Annoyance = unpleasant mental state (subjective)

Community and Environmental noise regulations NOT based on annoyance, but on loudness, despite noise at homes is rarely loud!

Human hearing and loudness perception

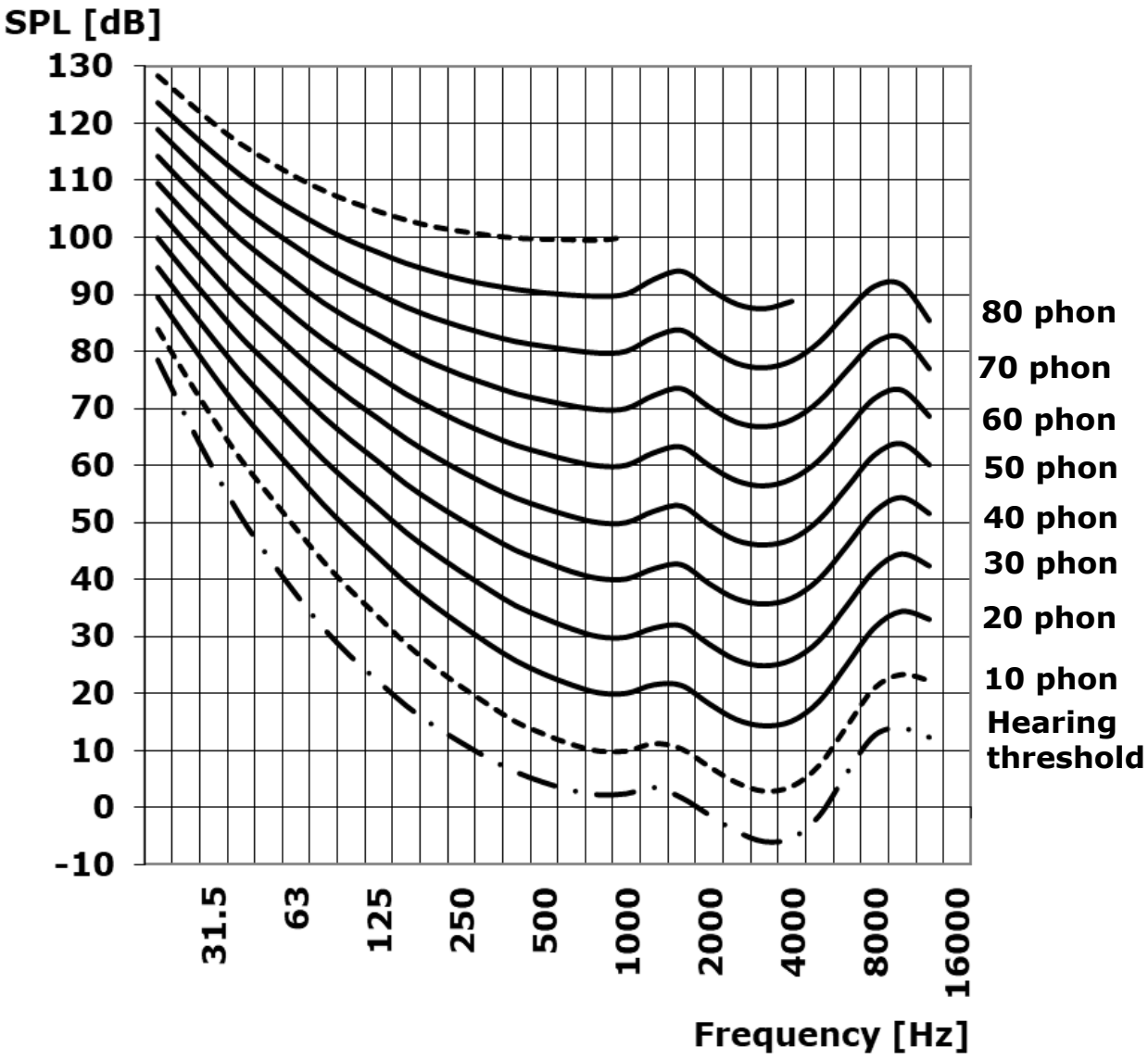


Figure: Equal loudness contours and hearing threshold according to ISO 226:2003

Loudness and A-weighted sound pressure level

$$L_{T_i}(F) = 10\log_{10}\left(\frac{1}{T_i}\int\left(\frac{p}{p_0}\right)^2 dt\right)$$

$$L(F) = 10\log_{10}\left(\frac{1}{T}\sum_{i=1}^{N} T_i 10^{0.1L_{T_i}(F)}\right)$$

$$L_A(F) = L(F) + k_A(F)$$

$$L_{A,eq} = 10\log_{10}\left(\sum_{F=1st\ oct}^{F=last\ oct} 10^{0.1L_{A(F)}}\right)$$

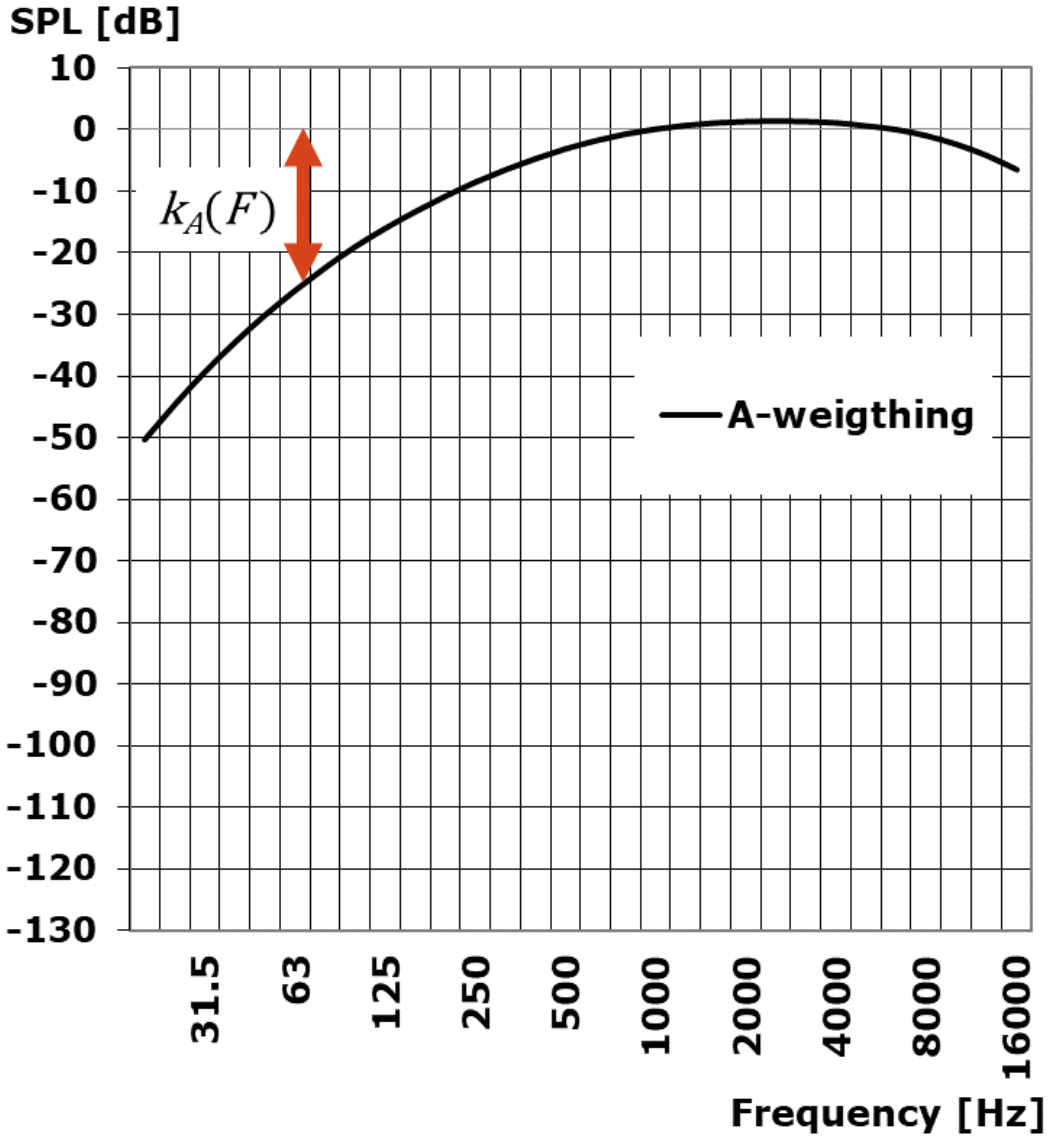


Figure: The A-weighting network as presented in IEC 61672-1:2013

Noise and health

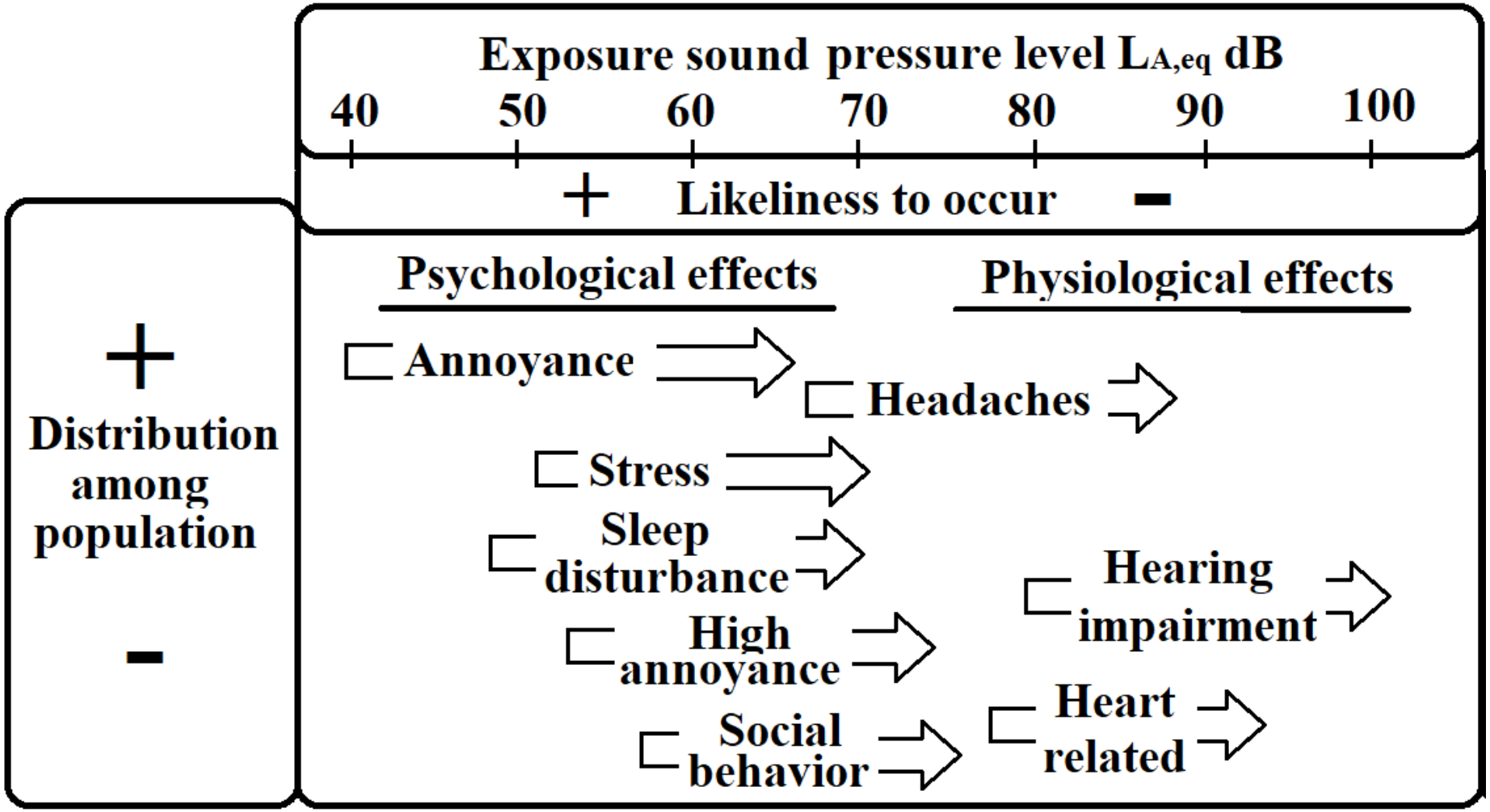
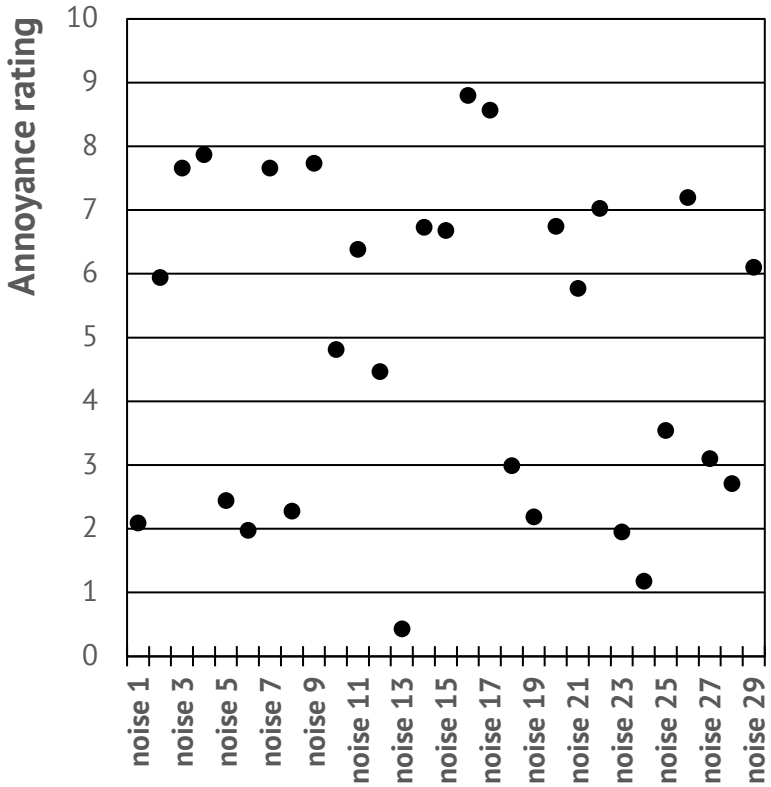
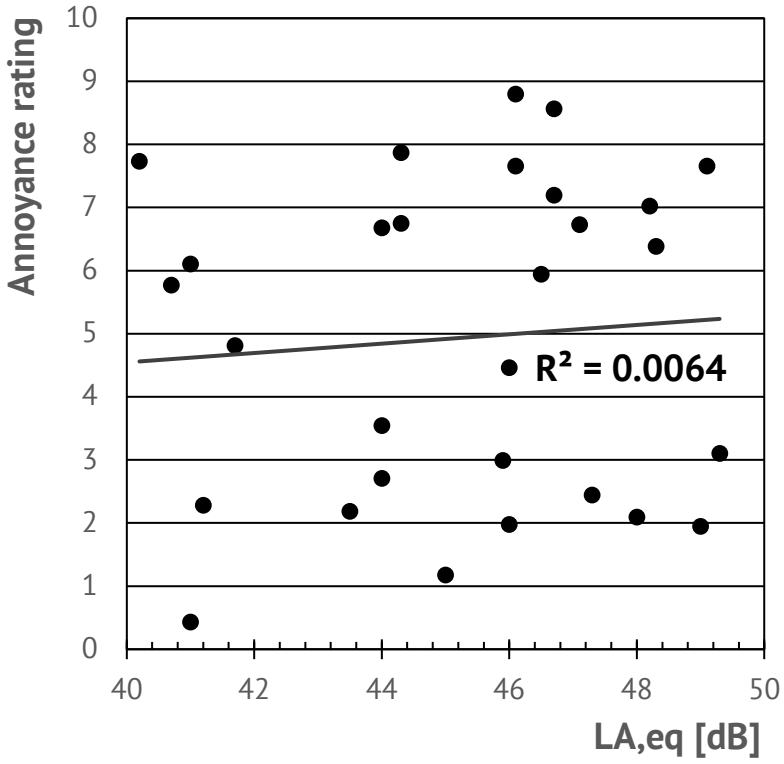


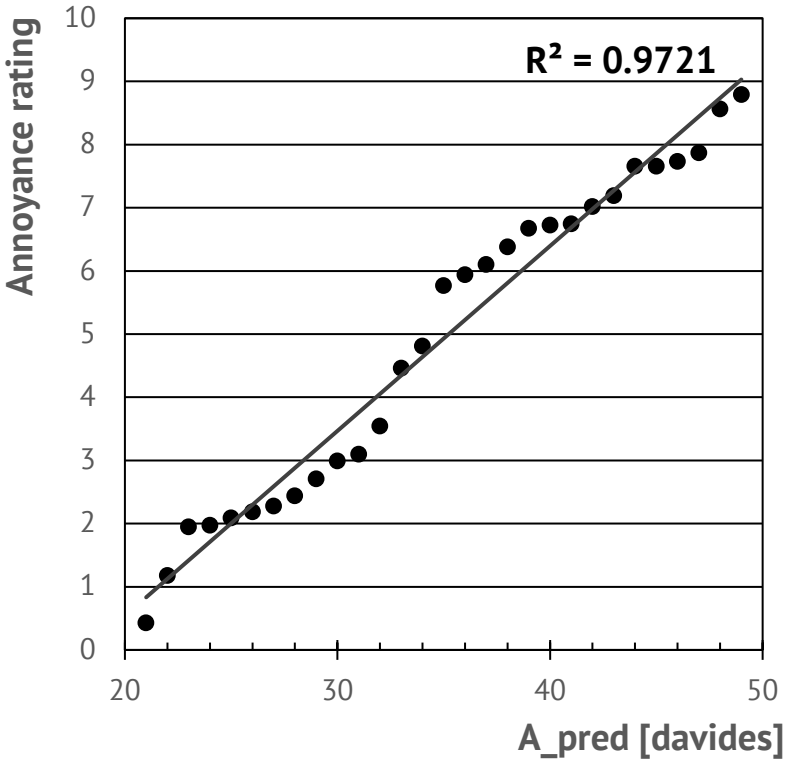
Figure: The most common psychological and physiological health effects of noise are ordered according to the sound pressure level $L_{A,eq}$ of exposure (after Oliva 2022)

Research question and hypothesis

What single number quantity correlates best with annoyance perception?



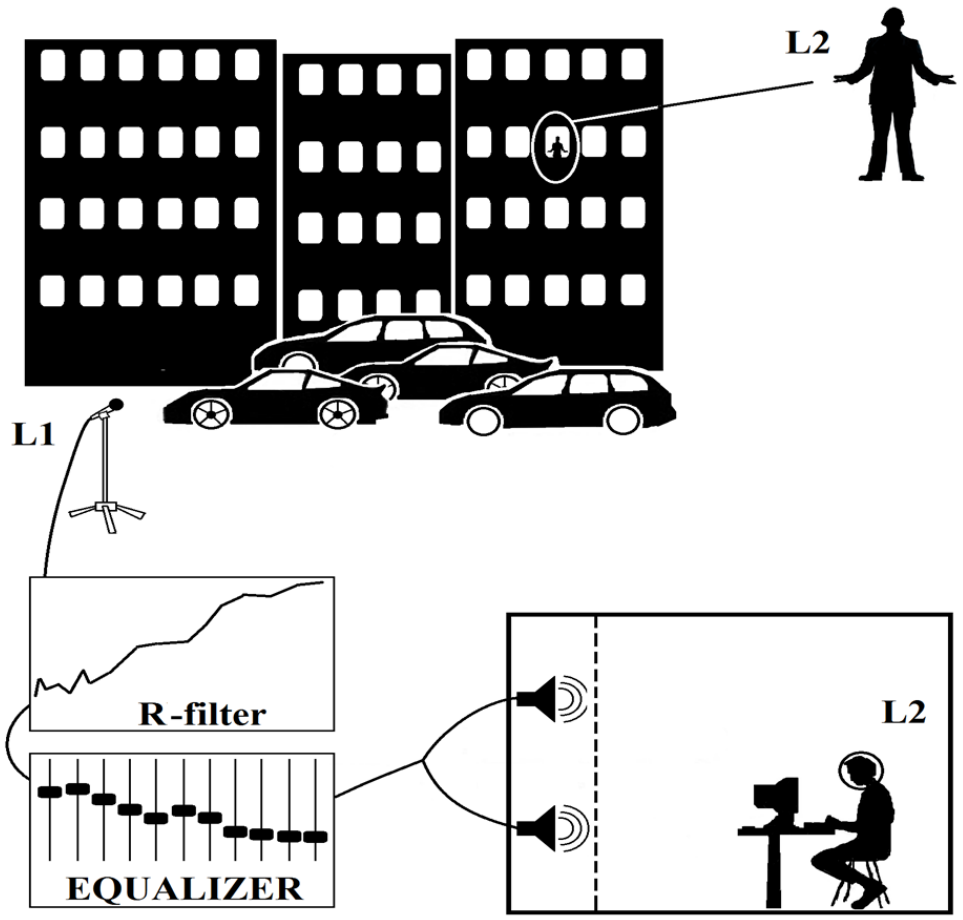




What is the *angle*?

Photo credit: Jami Aho

Experimental procedure



Imagine that you are at home in a relax state of mind. You read a book or a magazine when this noise starts to sound

How annoying this noise is?

Not annoying at all

Very annoying

○ ○ ○ ◉ ○ ○ ○ ○ ○ ○ ○

Laboratory setup

Publication I

Subjective and objective rating of spectrally different pseudorandom noises

Why | How | What

1. What **spectra** of ventilation noise leads to better acoustic satisfaction?

2. What **metrics** work best to describe the sound quality of ventilation noise in offices?

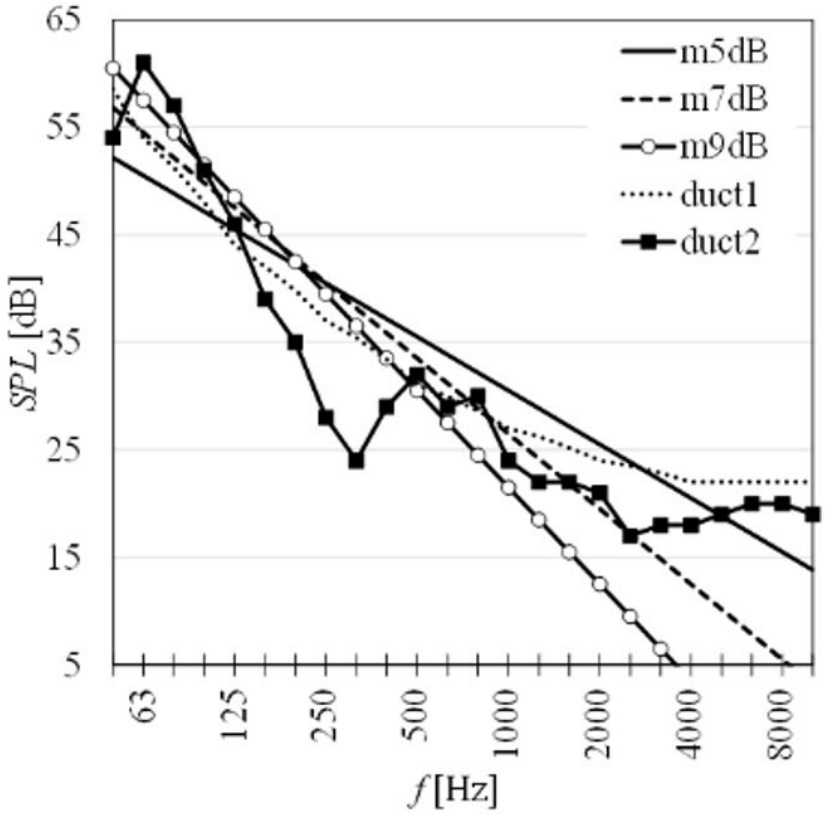
3. What background noise could be used as **speech masker** without producing annoyance?

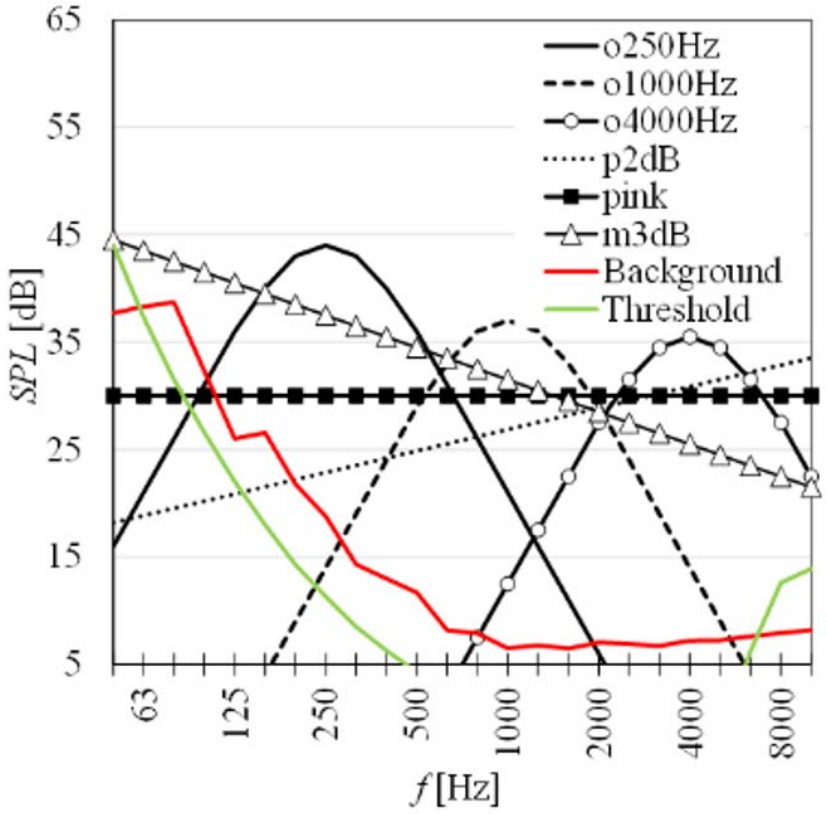
Photo credit: Oliva

Publication I

Subjective and objective rating of spectrally different pseudorandom noises

Why | **How** | What





11 ventilation noises
All with same $L_{A,eq}$ = 42 dB

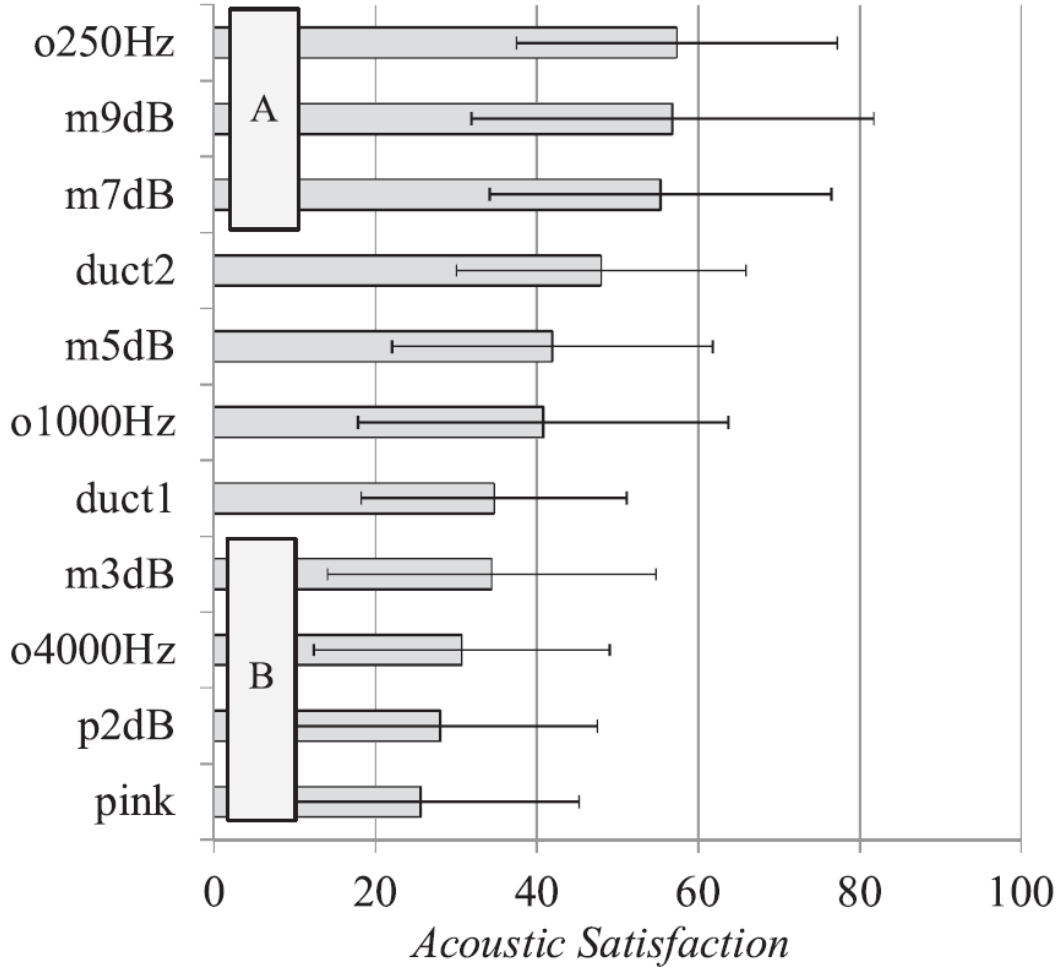
The conclusions are based on sum variable *acoustic satisfaction*, based on six subjective ratings

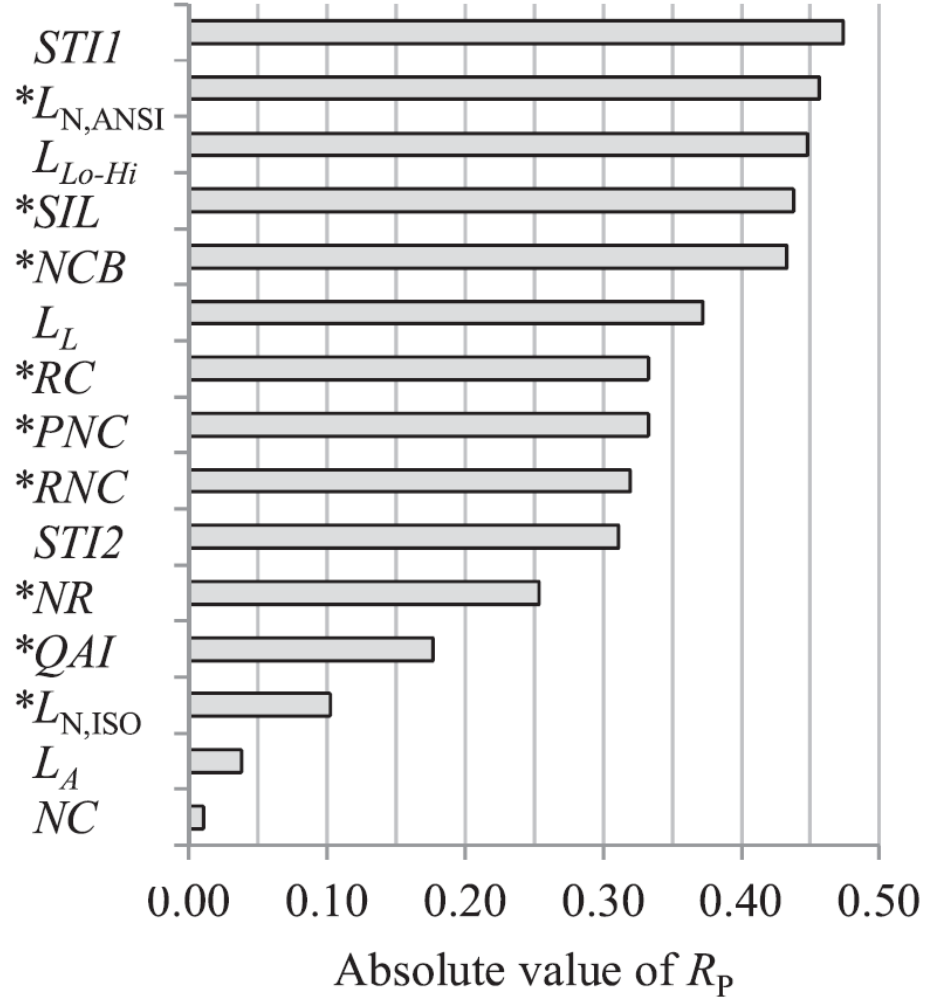
$$Acoustic\ Satisfaction = 1/6\ \{plea + habi + work + (100 - loud) + (100 - dist) + (100 - conc)\}$$

Publication I

Subjective and objective rating of spectrally different pseudorandom noises

Why → How → **What**





Publication II

Subjective and Objective Rating of Airborne Sound Insulation – Living Sounds

Why | How | What

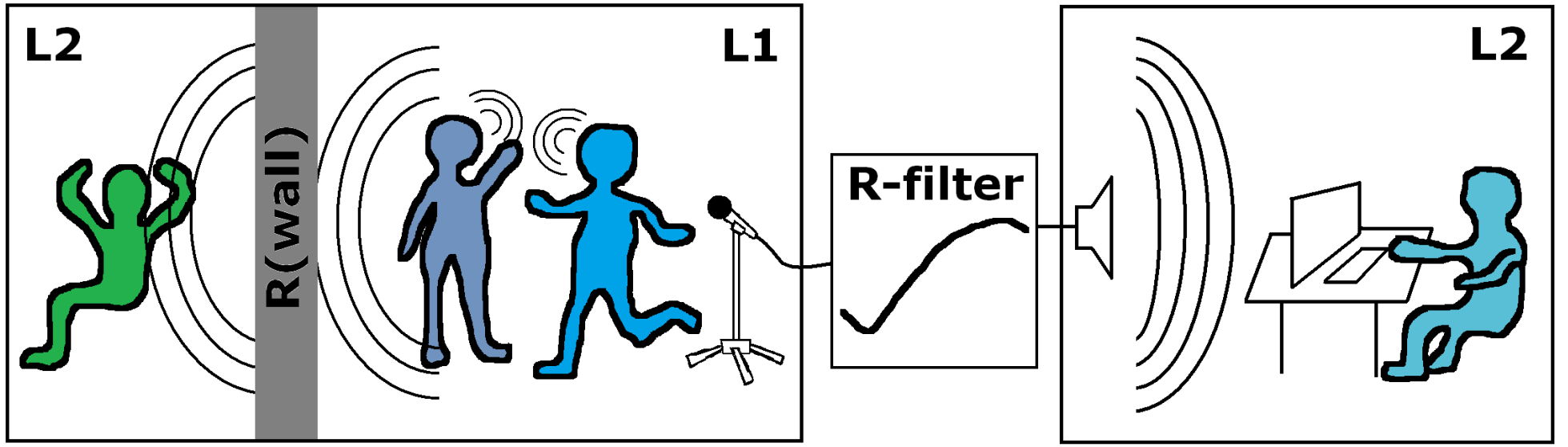
1. Which standardized **airborne sound insulation metric**, out of 12, predicts best the subjective annoyance rating of living sounds?

Photo credit: GETTY

Publication II

Subjective and Objective Rating of Airborne Sound Insulation – Living Sounds

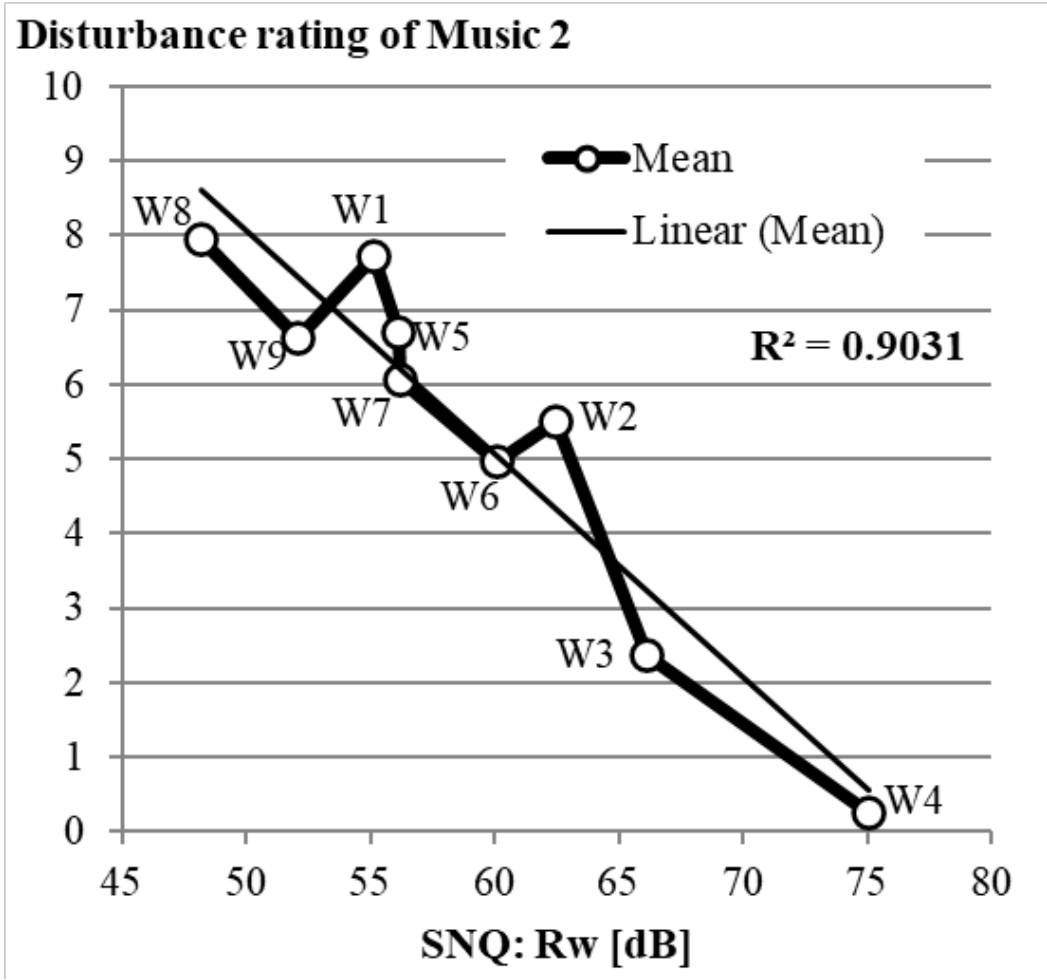
Why | **How** | What

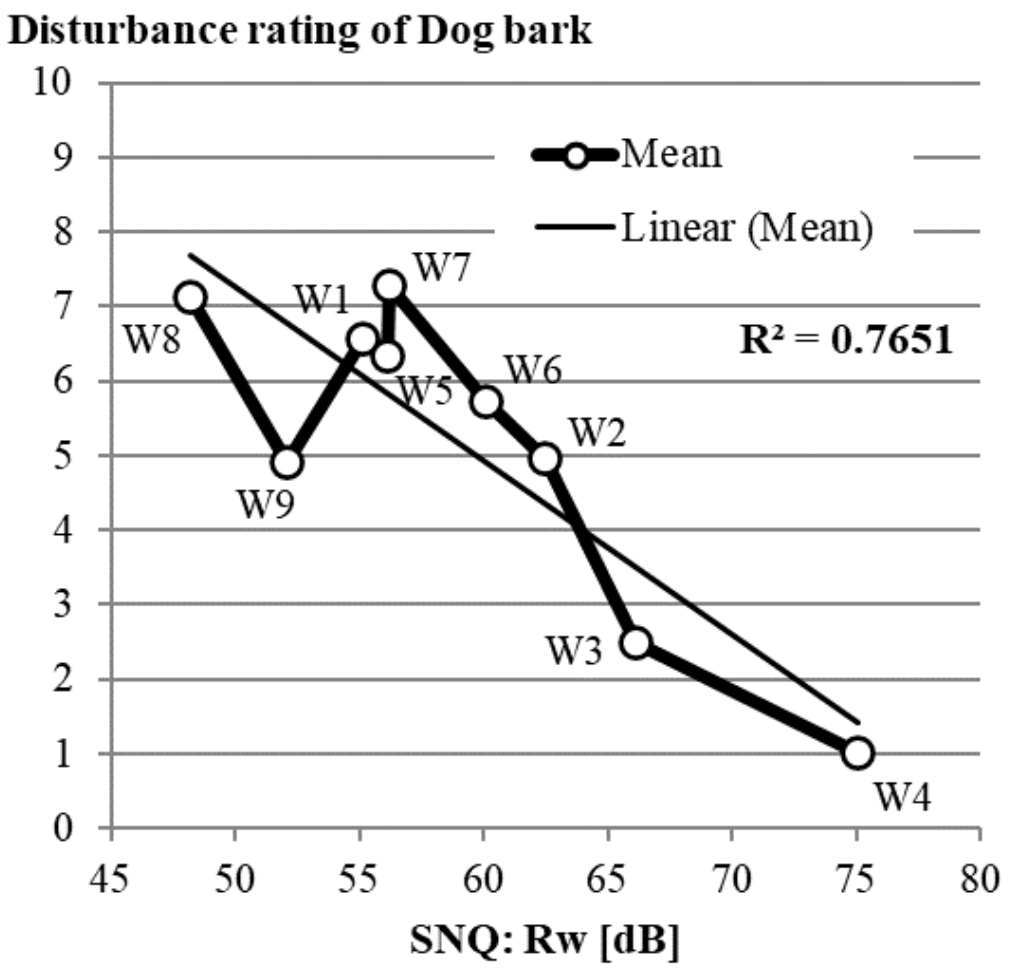


Publication II

Subjective and Objective Rating of Airborne Sound Insulation – Living Sounds

Why → How → **What**





Publication III

Subjective and objective rating of the sound insulation of residential building façades against road traffic noise

Why | How | What

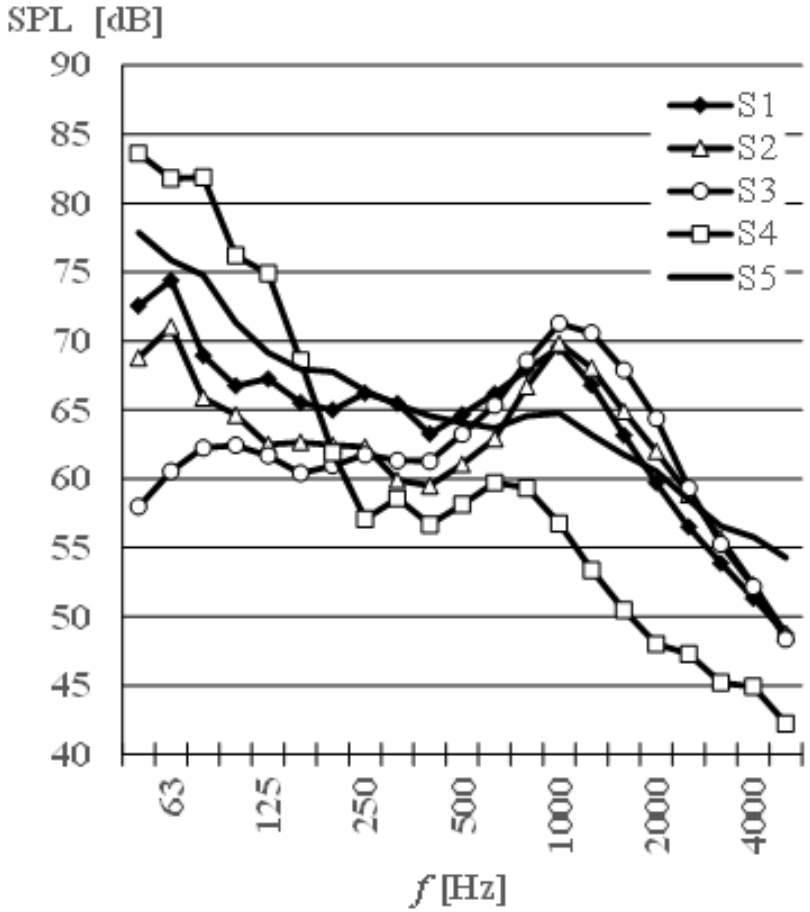
1. Which standardized **airborne sound insulation metric** applied to façade constructions, out of 25, predicts best the subjective annoyance rating of traffic noises?

Photo credit: Turun Sanomat, Heikki Kauhanen.
Noise is a serious noise problem.

Publication III

Subjective and objective rating of the sound insulation of residential building façades against road traffic noise

Why | **How** | What

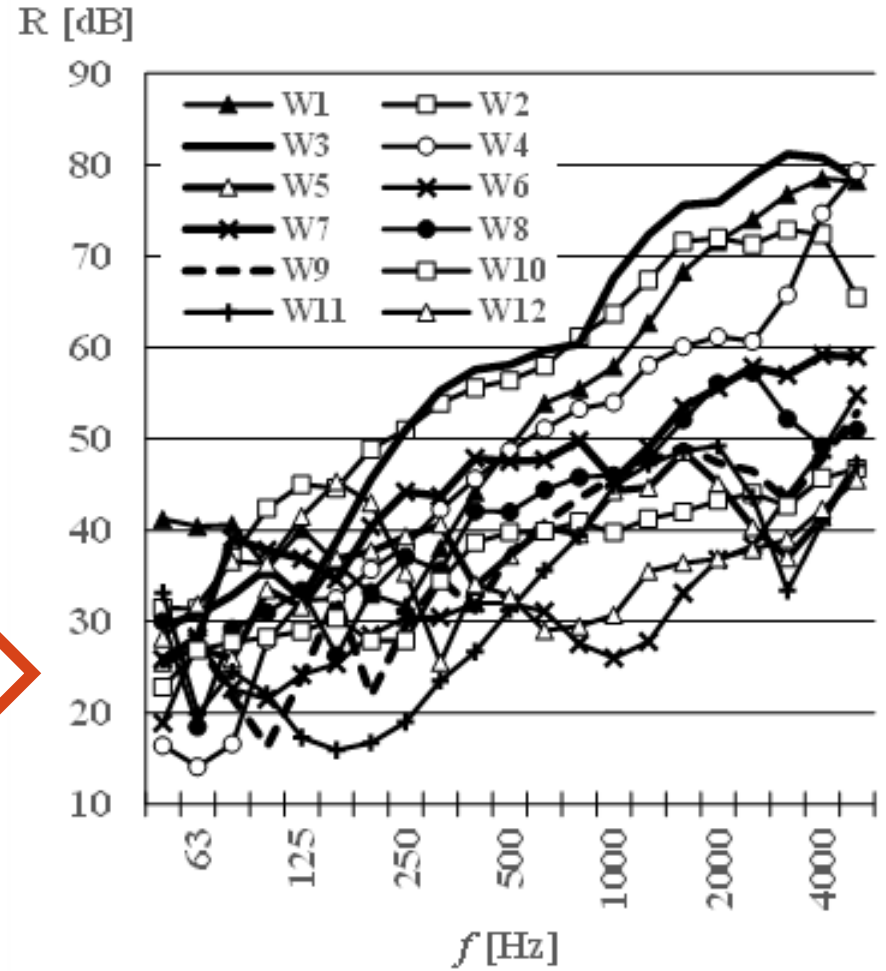


60 experimental sounds =

5 traffic noises
(S1 – S5)

*

12 façade constructions
(W1 – W12)



Publication III

Subjective and objective rating of the sound insulation of residential building façades against road traffic noise

Why → How → **What**

	Correlation coefficient				
SNQ	S1	S2	S3	S4	S5
R_w	0.55	0.56	0.64	0.21	0.50
$R_w + C_{100–3150}$	0.55	0.56	0.62	0.22	0.50
$R_w + C_{100–5000}$	0.55	0.56	0.62	0.21	0.50
$R_w + C_{50\text{-}3150}$	0.56	0.57	0.62	0.25	0.52
$R_w + C_{50–5000}$	0.56	0.57	0.62	0.25	0.52
$R_w + C_{tr,100–3150}$	0.53	0.53	0.57	0.24	0.49
$R_w + C_{tr,100–5000}$	0.53	0.53	0.58	0.24	0.50
$R_w + C_{tr,50–3150}$	0.50	0.51	0.50	0.33	0.50
$R_w + C_{tr,50–5000}$	0.50	0.51	0.50	0.33	0.50
$STA_{100–5000}$	0.55	0.56	0.62	0.21	0.50
$STA_{50–5000}$	0.56	0.57	0.62	0.25	0.52
$AA_{100–5000}$	0.51	0.55	0.63	0.21	0.48
$AA_{50–5000}$	0.51	0.55	0.62	0.24	0.48
STC	0.53	0.54	0.61	0.19	0.48
STC_{no8}	0.55	0.56	0.64	0.21	0.49
$EA_{100–5000}$	0.45	0.45	0.46	0.26	0.45
$EA_{50–5000}$	0.30	0.32	0.28	0.34	0.35

	Rank order					
SNQ	S1	S2	S3	S4	S5	Overall Rank
R_w	4	4	2	18	6	4
$R_w + C_{100–3150}$	6	7	6	14	7	6
$R_w + C_{100–5000}$	7	6	4	15	8	5
$R_w + C_{50\text{-}3150}$	3	3	12	6	2	2
$R_w + C_{50–5000}$	1	1	10	7	1	1
$R_w + C_{tr,100–3150}$	12	14	16	9	11	14
$R_w + C_{tr,100–5000}$	11	13	15	10	10	9
$R_w + C_{tr,50–3150}$	16	18	19	3	5	15
$R_w + C_{tr,50–5000}$	15	17	18	2	4	12
$STA_{100–5000}$	8	8	5	16	9	8
$STA_{50–5000}$	2	2	11	8	3	3
$AA_{100–5000}$	13	11	3	19	17	13
$AA_{50–5000}$	14	10	9	11	15	11
STC	10	12	13	22	16	16
STC_{no8}	5	5	1	20	12	7
$EA_{100–5000}$	20	20	21	5	18	19
$EA_{50–5000}$	23	23	23	1	23	21

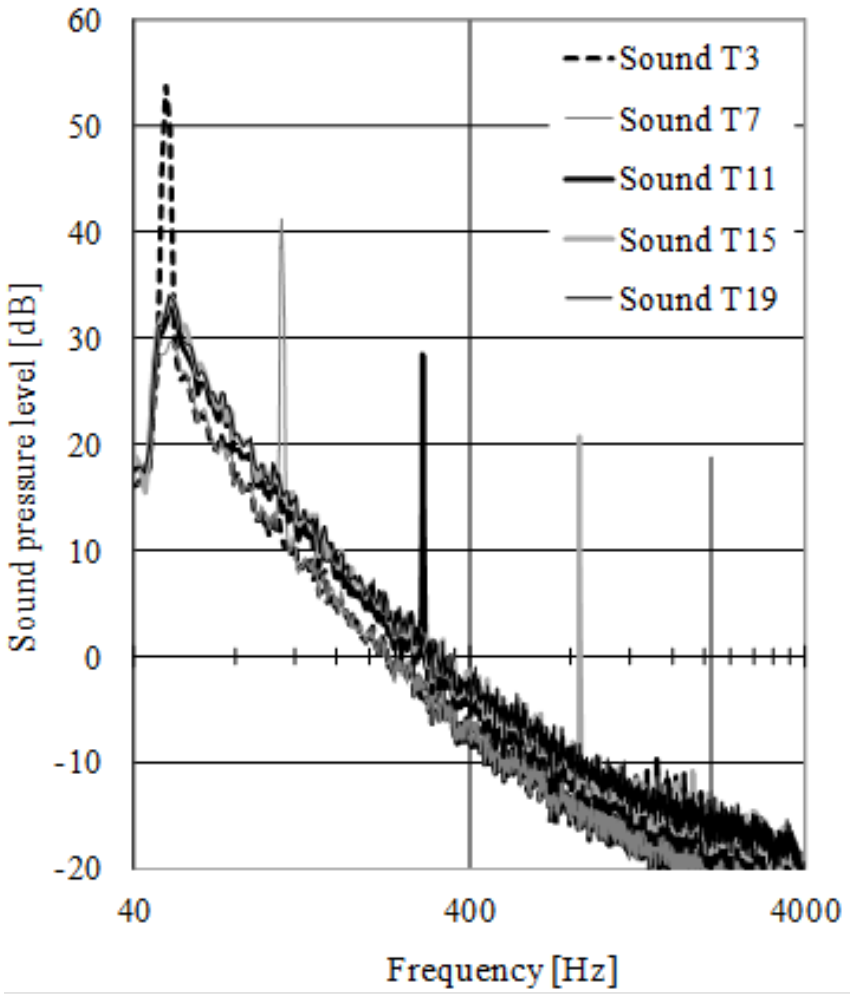
Publication IV

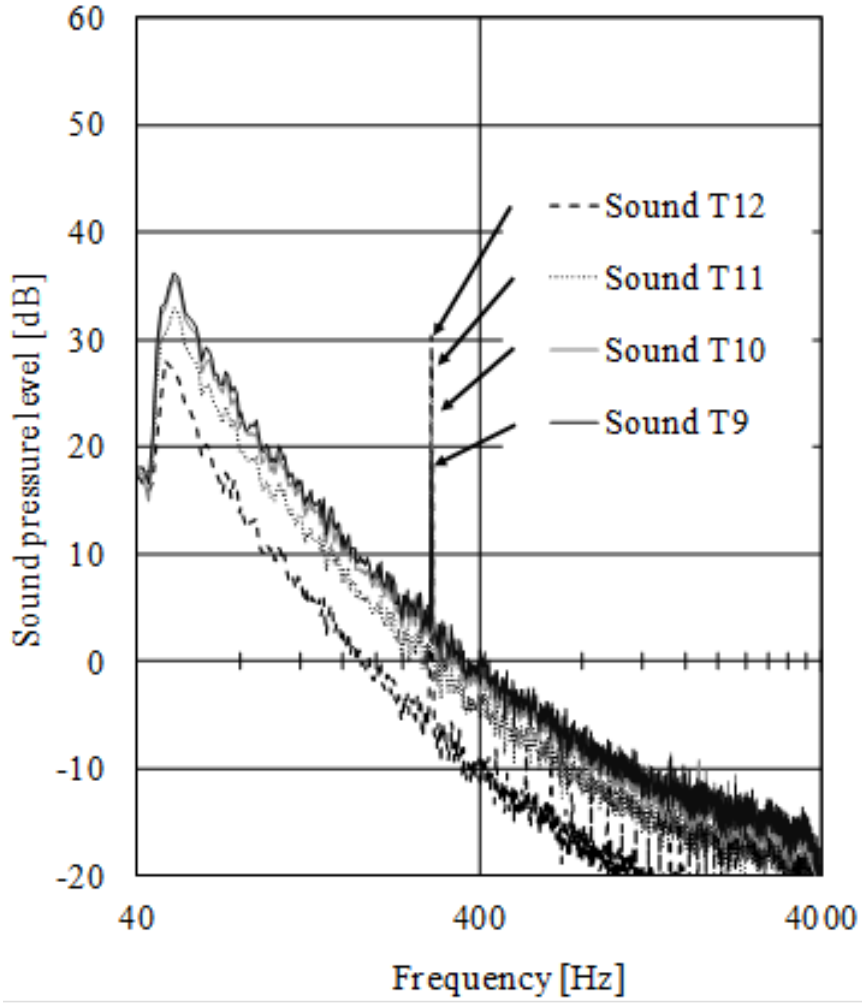
Annoyance of low-level tonal sounds – Factors affecting the penalty

Why | How | What

1. How the **frequency** and the **audibility** of the tone affects annoyance?

2. What **penalty** should be added to tonal sounds?

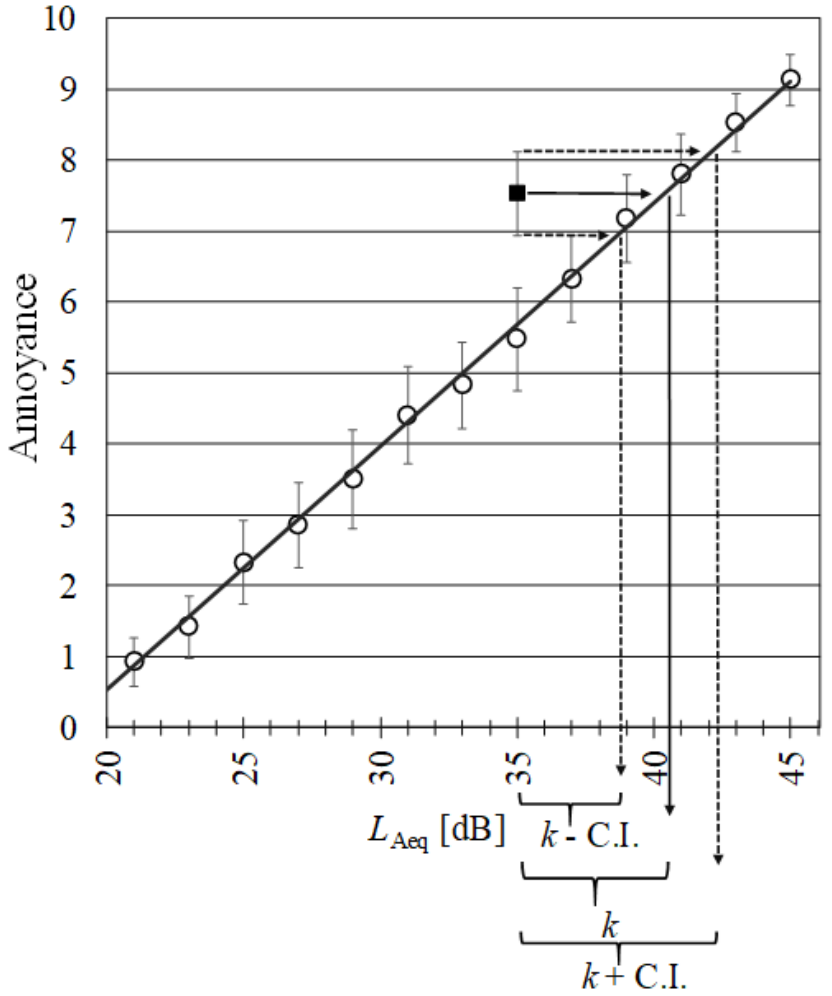




Publication IV

Annoyance of low-level tonal sounds – Factors affecting the penalty

Why | **How** | What



Example of the determination of penalty value *k* for the experimental sound with overall level 35 dB $L_{A,eq}$, tonal frequency 850 Hz, and tonal audibility 17 dB.

The penalty (line with arrow) and its uncertainty (dashed line with arrows) determined by the 95% confidence interval were determined by finding the apparent level of the equally annoying non-tonal sound using the fitted line.

In this case, the penalty was k = 5.3 dB and the confident interval C.I. = 0.9.

Publication IV

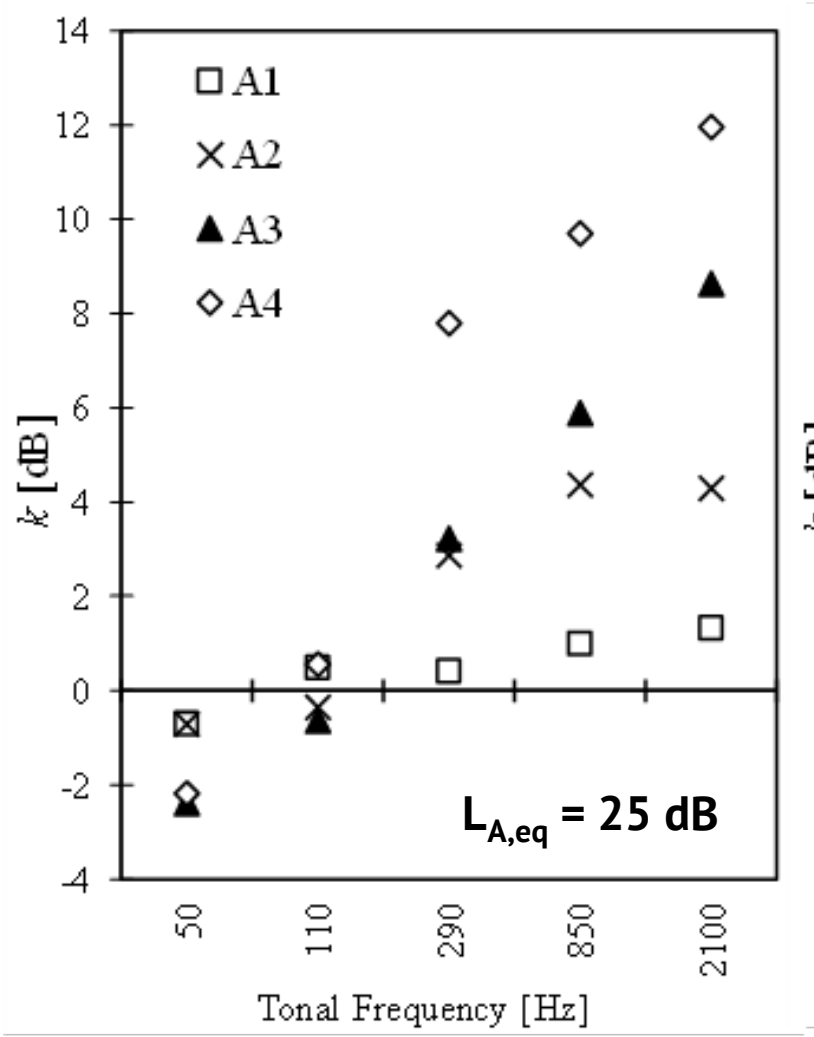
Annoyance of low-level tonal sounds – Factors affecting the penalty

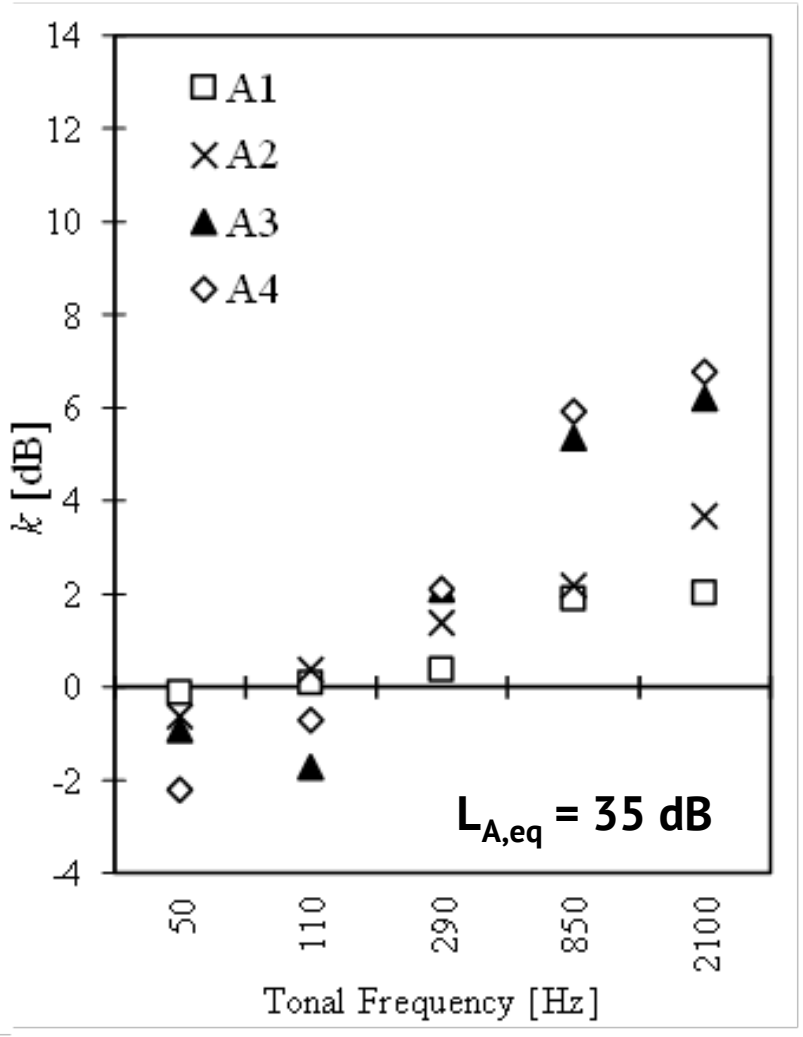
Why | How | **What**

A penalty could be applied to compensate extra annoyance experience produced by tonal sounds. But not always!

Penalty depends on sound pressure level, tonal frequency and tonal audibility.

In Finland, current noise regulations give a constant penalty of 6 dB, independently of tonal frequency or sound pressure level.





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Ja mitä tämä kaikkia tarkoittaa?

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Kiitos!