Environmental Impacts, Threshold Levels and Health Effects

Lecture 12: Noise Part 6 (20.05.2020)

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D-USYS

Homepage:
http://www.noise.ethz.ch/ei/
Topics covered in the previous lecture

- Questions from students from previous lecture
- Sleep disturbances: study types and methods
- Polysomnography (PSG)
- Actimetry / Actigraphy / Seismosomnography
- Sleep disturbances: Awakening probability
- Countermeasures / noise abatement in the night
- Long-term health effects of noise
- Cardiovascular effects
Lecture overview for today

- Long-term health effects (cont'd)
  - Metabolic effects
  - Effects on cognitive performance
  - The question of causality, study types in epidemiology

- Quantifying the costs of noise

- Noise abatement and regulation of noise
  - Principles of noise abatement in Switzerland
  - Noise exposure limits in the Swiss noise abatement regulation

- Final conclusions
Long term metabolic effects of noise

Type 1 Diabetes

Type 2 Diabetes (insulin resistance)
Oral glucose tolerance after noisy nights (SiRENE study)

Legend:

- Baseline ("no noise") $L_{Aeq,1h} : 30$ dB
- Road traffic or railway noise simulations $L_{Aeq,1h} : 45$ dB
- Polysomnography
- Oral Glucose Tolerance Test (OGTT)
Oral glucose tolerance after noisy nights (SiRENE study)

**Glucose**

- Black: After baseline night
- Red: After last noise-nights
- Green: After recovery night

**Insulin**

- Black: After baseline night
- Red: After last noise-nights
- Green: After recovery night

* p<0.05; vs. BL
Diabetes risk increase per 10 dB (SiRENE/SAPALDIA study)

Eze IC et al. Int J Epidemiol, 2017
Effects of noise on (cognitive) performance

**RANCH study (Stansfeld et al., 2005) -- Aircraft noise**

- Exposure-effect model for reading performance

![Diagram showing the relationship between aircraft noise exposure (LAeq) and reading performance. The x-axis represents aircraft noise dB(A) from 30 to 70, and the y-axis represents reading performance Z score from -0.4 to 0.4. The graph shows a decrease in reading performance with increasing noise levels.]

Aircraft noise exposure, LAeq, 07:00-23:00 h, [dB(A)]
Effects of noise on (cognitive) performance

NORAH study (Klatte et al., 2015) -- Aircraft noise

- Exposure-effect model for reading performance

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**Graph:**
- Y-axis: Adjusted T-value of reading performance
- X-axis: Aircraft noise exposure, LAeq, 08:00-14:00 h [dB(A)]
- Data points for different noise exposure levels:
  - ≤ 40 dB(A)
  - >40 bis ≤ 45 dB(A)
  - >45 bis ≤ 50 dB(A)
  - >50 bis ≤ 55 dB(A)
  - >55 bis ≤ 60 dB(A)

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## Causality?
"Bradford-Hill criteria" (1965)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of association:</td>
<td>stronger associations are more likely to have a causal component</td>
</tr>
<tr>
<td>Consistency:</td>
<td>the association must be seen consistently across studies or populations</td>
</tr>
<tr>
<td>Specificity:</td>
<td>the association must produce a specific endpoint</td>
</tr>
<tr>
<td>Temporality:</td>
<td>the factor being advocated as causative must precede the outcome</td>
</tr>
<tr>
<td>Biological gradient:</td>
<td>the outcome must be obtained in a dose-responsive manner</td>
</tr>
<tr>
<td>Plausibility:</td>
<td>the causal explanation must be biologically plausible</td>
</tr>
<tr>
<td>Coherence:</td>
<td>a cause-and-effect interpretation of the data should not contradict present knowledge</td>
</tr>
<tr>
<td>Experimental support:</td>
<td>the association is experimentally supported</td>
</tr>
</tbody>
</table>

Study types in epidemiology

- Systematic Review/Meta-Analysis
- Randomized Controlled Trial
- Case Reports and Series
- Ideas, Opinions, Editorials
- Animal Research
- Invitro "test tube" research

Increasing evidence strength
Quantifying the costs of noise
Quantifications of the "cost" of noise on an aggregate level (I)

Disability Adjusted Life Years (DALY) lost in Switzerland

Source: Ecoplan (2014): Auswirkungen des Verkehrslärms auf die Gesundheit
Quantifications of the "cost" of noise on an aggregate level (II)

*External costs of transportation noise in CHF, Switzerland, 2005*

![Graph showing the costs of noise in CHF for rent deficits, healthcare costs, passenger traffic, and goods traffic.](image)

Source: Bundesamt für Raumentwicklung, 2008
Quantifications of the "cost" of noise on an aggregate level (III)

*External costs of transportation*, Switzerland, 2005, in Million CHF

Total external costs: 8 529 000 000 CHF per year
thereof: 1 174 000 000 CHF due to noise

<table>
<thead>
<tr>
<th>Source: Bundesamt für Raumentwicklung, 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>External costs of transportation, Switzerland, 2005, in Million CHF</td>
</tr>
<tr>
<td>Total external costs: 8 529 000 000 CHF per year</td>
</tr>
<tr>
<td>thereof: 1 174 000 000 CHF due to noise</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unfälle (Sicht Verkehrsträger)</th>
<th>Strasse</th>
<th>Schiene</th>
<th>Total</th>
<th>Total in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2'047</td>
<td>2'017</td>
<td>30</td>
<td>2'047</td>
<td>24.0%</td>
</tr>
</tbody>
</table>

| Lärm | | | | |
| 1'174 | 1'101 | 74 | 1'174 | 13.8% |

| Gesundheitskosten der Luftverschmutzung | | | | |
| 1'954 | 1'834 | 120 | 1'954 | 22.9% |

| Gebäude schäden der Luftverschmutzung | | | | |
| 289 | 274 | 15 | 289 | 3.4% |

| Klima | | | | |
| 1'264 | 1'256 | 7 | 1'264 | 14.8% |

| Natur und Landschaft | | | | |
| 797 | 687 | 110 | 797 | 9.3% |

| Ernteausfälle | | | | |
| 65 | 63 | 2 | 65 | 0.8% |

| Waldschäden | | | | |
| 66 | 64 | 2 | 66 | 0.8% |

| Bodenschäden | | | | |
| 140 | 107 | 33 | 140 | 1.6% |

| Zusatzzkosten in städtischen Räumen | | | | |
| 99 | 78 | 20 | 99 | 1.2% |

| Vor- und nachgelagerte Prozesse | | | | |
| 634 | 593 | 41 | 634 | 7.4% |

| Total | | | | |
| 8'529 | 8'074 | 455 | 8'529 | 100.0% |

| Anteil an Total | | | | |
| 94.7% | 5.3% | 100.0% |
Quantifications of the "cost" of noise on an aggregate level (IV)

Hedonic pricing analysis – reduction of rent/property value per 1 dB

<table>
<thead>
<tr>
<th>Autor</th>
<th>Ort</th>
<th>Anzahl Beobachtungen</th>
<th>Abnahme Wohnungspreis pro dB Taglärm</th>
<th>Abnahme Wohnungspreis pro dB Nachlärm</th>
<th>Schwellenwert Taglärm</th>
<th>Schwellenwert Nachlärm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecoplan 2001</td>
<td>Kanton Zürich 1995-99</td>
<td>380 Einfamilienhäuser / Eigentumswohnungen</td>
<td>Strasse: 0.66%</td>
<td></td>
<td>55 dB(A)</td>
<td></td>
</tr>
<tr>
<td>Baranzini / Ramirez 2005</td>
<td>Kanton Genf</td>
<td>13'064 Mietwohnungen</td>
<td>0.28%</td>
<td></td>
<td>50 dB(A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agglomeration Genf Land (Restkanton Genf)</td>
<td>10'018 Mietwohnungen</td>
<td>0.20%</td>
<td>50 dB(A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freier Markt</td>
<td>3'073 Mietwohnungen</td>
<td>0.63%</td>
<td>50 dB(A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staatlich subventioniert</td>
<td>10'394 Mietwohnungen</td>
<td>0.15%</td>
<td>50 dB(A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2'840 Mietwohnungen</td>
<td>0.70%</td>
<td>50 dB(A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baranzini et al. 2006</td>
<td>Kanton Genf</td>
<td>2794 Mietwohnungen</td>
<td>0.18% – 0.22%</td>
<td></td>
<td>50 / 55 dB(A)</td>
<td></td>
</tr>
<tr>
<td>Baranzini / Schärer 2007</td>
<td>Kanton Genf</td>
<td>10'396 Mietwohnungen</td>
<td>Strasse: 0.20% – 0.23%</td>
<td></td>
<td>50 dB(A)</td>
<td></td>
</tr>
<tr>
<td>Schäerer et al. 2008</td>
<td>Stadt Genf</td>
<td>3'327 Mietwohnungen</td>
<td>Strasse: 0.17% – 0.20%</td>
<td></td>
<td>50 dB(A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stadt Zürich</td>
<td>3'194 Mietwohnungen</td>
<td>Strasse: 0.37% – 0.38%</td>
<td></td>
<td>55 dB(A)</td>
<td></td>
</tr>
<tr>
<td>Banfi et al. 2007</td>
<td>Stadt Zürich</td>
<td>6'204 Mietwohnungen</td>
<td>Strasse: 0.2%</td>
<td>0.31%</td>
<td>55 dB(A)</td>
<td>50 dB(A)</td>
</tr>
<tr>
<td></td>
<td>Stadt Lugano</td>
<td>547 Mietwohnungen</td>
<td>Strasse: 0.5%</td>
<td>0.60%</td>
<td>55 dB(A)</td>
<td>50 dB(A)</td>
</tr>
<tr>
<td>ZKB (2005), MIFLU¹</td>
<td>Flughafen Zürich</td>
<td>Eigentumswohnungen</td>
<td>Luftfahrt: 1.2%</td>
<td></td>
<td>50 dB(A)</td>
<td>50 dB(A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Einfamilienhäuser</td>
<td>Luftfahrt: 0.87%</td>
<td></td>
<td>50 dB(A)</td>
<td></td>
</tr>
<tr>
<td>Scognamiglio²</td>
<td>Schweiz</td>
<td>ca. 2'000 Transaktionen von Renditelegenschaften</td>
<td>Luftfahrt: 1.2%</td>
<td>1.8%</td>
<td>45 dB (A)</td>
<td>40 dB (A)</td>
</tr>
<tr>
<td>ZKB 2012</td>
<td>Schweiz</td>
<td>855'693 Mietwohnungen</td>
<td>Strasse: 0.21%</td>
<td>Schiene: 0.24%</td>
<td>0.21%</td>
<td>0.24%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83'856 Stockwerk-eigentumswohnungen</td>
<td>Schiene: 0.47%</td>
<td>0.59%</td>
<td>0.47%</td>
<td>0.59%</td>
</tr>
</tbody>
</table>
Noise abatement and regulation of noise
Rationale for noise abatement

Noise is undesirable sound that can harm human health and interfere with people’s daily activities at school, at work, at home and during leisure time.

It can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behavior.

Noise causes economic losses (health costs, abatement measures, reduced value of real estate property etc.).
Roles of Science and of Policy in noise abatement

Risk Assessment

Risk Management

Action plans

Science

Policy
The six basic principles of noise abatement in Switzerland

1. **Assessment principle**
   - Exposure-effect

2. **Source principle**
   - Abatement Measures

3. **Prevention principle**
   - Future noise problems

4. **Remediation principle**
   - Existing noise problems

5. **Polluter pays principle**
   - Noise costs

6. **Cooperation principle**
   - Role of players
"Pull" and "Push" measures

**Incentives**
- Technical feasibility (research)
- Subventions
- Economic Incentive instruments

**Enforcement**
- Regulations (emission limits, exposure limits)
- Penalties, compensations
Noise abatement as a feedback-controlled system

- Source
  - Encapsulation
  - Muffling
  - Operational restrictions

- Propagation
  - Walls
  - Barriers

- Sound proof windows

- Receiver

- Measures Rules

- Effective level (Rating level)

- Target level (Limit value)
Exposure limits in Swiss noise legislation

The rating level \( L_r \)

\[
L_r = \text{Leq} + K
\]

Rating Level \( L_r \) [dB] = Average Level + Correction

\( \rightarrow \) The Rating Level \( L_r \) is not a physical measure, but a measure for the noise effect! (but it is expressed in dB)
Exposure limits in the Swiss noise abatement legislation

Definition of three types of limit values

Noise exposure

Alarm values for assessing the urgency of abatement measures and as a criterion for fitting soundproof windows.

Immission limit values must be set so that, in the light of current scientific knowledge and experience, immissions below these levels will not seriously disturb the well-being of the population.

Planning values for permitting the construction of new installations and for ruling out and development of new building areas (land use planning).
Exposure limits in Swiss noise legislation

Limit values on an exposure-effect curve

- Planning value PV
- Alarm value AW
- Immission limit value ILW
Assessment of % highly annoyed (%HA)
... using ICBEN scales

Serious annoyance of the population (highly annoyed)

Extremely
Very
Moderately
Slightly
Not at all
**Exposure limits in Swiss noise legislation**

*Method for setting limit values in Lr [dB]*

<table>
<thead>
<tr>
<th>Sensitivity categories</th>
<th>Planning value</th>
<th>Immission limit value</th>
<th>Alarm value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection Zones (ES I)</td>
<td>x-10</td>
<td>X-5</td>
<td>x+5</td>
</tr>
<tr>
<td>Residential Areas (ES II)</td>
<td>x-5</td>
<td>X</td>
<td>x+10</td>
</tr>
<tr>
<td>Mixed Areas (ES III)</td>
<td>x</td>
<td>X+5</td>
<td>x+10</td>
</tr>
<tr>
<td>Industrial Areas (ES IV)</td>
<td>x+5</td>
<td>X+10</td>
<td>x+15</td>
</tr>
</tbody>
</table>
Exposure limits in Swiss noise legislation
Noise abatement ordinance ("Lärmschutzverordnung")

Exposure limits (in the measure "Lr") for road traffic noise
Day = 06:00-22:00
Night = 22:00-06:00

<table>
<thead>
<tr>
<th>Sensitivity category</th>
<th>Planning value Day</th>
<th>Planning value Night</th>
<th>Immission limit value Day</th>
<th>Immission limit value Night</th>
<th>Alarm value Day</th>
<th>Alarm value Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Protection zones</td>
<td>50</td>
<td>40</td>
<td>55</td>
<td>45</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>II Residential areas</td>
<td>55</td>
<td>45</td>
<td>60</td>
<td>50</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>III Mixed areas</td>
<td>60</td>
<td>50</td>
<td>65</td>
<td>55</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>IV Industrial areas</td>
<td>65</td>
<td>55</td>
<td>70</td>
<td>60</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>
Exposure limits in Swiss noise legislation

**Noise abatement ordinance ("Lärmschutzverordnung")**

### Exposure Limit Values for Road Traffic Noise

1. **Scope**
   - The exposure limit values specified in Number 2 apply to road traffic noise. This includes noise on roads from motor vehicles (motor vehicle noise) and railways (railway noise).

2. **Exposure limit values**

<table>
<thead>
<tr>
<th>Sensitivity level (Art. 42)</th>
<th>Planning value $L_r$ in dB(A)</th>
<th>Ambient limit value $L_{an}$ in dB(A)</th>
<th>Alarm value $L_{an}$ in dB(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Night</td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>I</td>
<td>50</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>II</td>
<td>55</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>III</td>
<td>60</td>
<td>50</td>
<td>65</td>
</tr>
<tr>
<td>IV</td>
<td>65</td>
<td>55</td>
<td>70</td>
</tr>
</tbody>
</table>

3. **Determination of the Rating Sound Level**

   - **31 Principles**
     1. The rating sound level $L_r$ for road traffic noise is determined from the partial rating sound levels for motor vehicle noise ($L_{r1}$) and railway noise ($L_{r2}$) as follows:
        $$L_r = 10 \cdot \log \left(10^{L_{r1}/10} + 10^{L_{r2}/10}\right)$$
     2. The partial rating sound level $L_{r1}$ is the sum of the equivalent continuous A-weighted sound level $L_{eq,m}$ resulting from motor vehicles, and the level correction $K_1$:
        $$L_{r1} = L_{eq,m} + K_1$$
     3. The partial rating sound level $L_{r2}$ is the sum of the equivalent continuous A-weighted sound level $L_{eq,b}$ resulting from the railways, and the level correction $K_2$:
        $$L_{r2} = L_{eq,b} + K_2$$
     4. The partial rating sound levels $L_{r1}$ and $L_{r2}$ are determined for average day and night traffic flows assuming a dry road surface.
Example: Aircraft noise contours...

...at the Planning, Immission limit and Alarm values (Lr for day period)

Source: http://www.fluglaerm-frankfurt.de/349.0.html

Lr=57 dB(A): Planning value
Lr=60 dB(A): Immission limit value
Lr=65 dB(A): Alarm value
Number of residents above Immission limit values during day
.. in Switzerland (2009)

Quelle: Bundesamt für Umwelt © BFS
Final conclusions for the Part "Noise" (I)

After all, how harmful is noise at the end?

- Science is well able to demonstrate **effects**, but less so in (clearly) demonstrating **damage**.

- Any health effect assessment depends on an accepted definition of what constitutes "health" (cp. the definition of health by the WHO)

- Exposure limit values are **normative postulates** (that means, they are often the result of a political compromise and hence not directly derived from scientific findings...)

- **Effects:** Cardiovascular effects starting at 45 dB(A) $L_{Day}$ (outdoors)
  - Awakening reactions as low as ca. 33 dB(A) $L_{max}$ (indoors)
  - No threshold observed with annoyance

- People react differently to noise → On the individual level, noise effects can occur as low as at 0 dB!
Final conclusions for the Part "Noise" (II)
What kind of statements can noise effects research make?

- Results that consistently show associations between noise exposure and effects across different studies suggest that this relationship is \textit{causal} (even if this can often not be 'proven' in the strong sense)

- Statements about exposure-effect relationships are possible only on the population or sample level

- Individual predictions are not possible

- Effects = Ratios, Probabilities, Percentages, Calculated risks...

- \textbf{Precautionary principle} is important: Although sometimes the available evidence lacks the demonstration of a clear relationship between exposure and health effects, a scientifically well founded \textit{presumption} suffices to take appropriate measures
Final conclusions for the Part "Noise" (III)

Issues/research gaps in noise effects research

- **Uncertainties** concerning the exposure (exposure history) of individuals (exposure misclassification bias) in epidemiological and observational studies

- *(Usually)* weak relationship between exposure and effects

- No established **quality standards** for noise effects studies

- Data about noise exposure are usually based on metrics and methods that are defined in regulations (often, other interesting noise metrics are not available, e.g. frequency distribution of the maximum sound pressure level etc.)

- No possibility to carry out (field)-experiments (but only observational studies)

- Research often takes place in a politically defined context with many conflicting interests
Some information regarding the "Sessionsprüfung"

Date, time, and place: Use official ETH channels...
Supervisor: Christian Monn
Duration: 60 Minutes
Credit points: 3
Weighting: 50% Air pollution part (Ch. Monn)
            50% Noise part (M. Brink)
Type of test: Written examination, you are asked to:
              - Answer multiple choice questions
              - List keywords
              - Draw diagrams
              - Label diagrams, flow charts etc.
Allowed helpers: Everything on paper (Books, Your own notes, Handouts of slides...)
Recommended: Lecture handouts and your notes
Not allowed: Laptops, Tablets, Smartphones etc.
Thank you very much for your attention!