Effect of speech on performance – an evidence-based model promoting noise control in offices

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Background

- According to several independent field surveys, noise is the most adverse factor of IE in open-plan offices.
  - Frontzcac et al 2012 *Indoor Air*
- Speech is the most distracting type of office noise
  - *Haapakangas et al. ICBEN 2004*
- Laboratory experiments have shown that speech impairs the performance of cognitively demanding tasks
  - Colle and Welsh 1976 *J Verbal Learn Verbal Behav*
  - Vast number of successors; see review by Hongisto 2005 *Indoor Air*
  - Speech intelligibility determines the distracting power of speech primarily, not the sound pressure level of speech.
    - Colle 1980 *J Verbal Learn Verbal Behav*

- A well-documented objective descriptor of subjective speech intelligibility is STI
  - IEC 60268-16
  - Houtgast&Steeneken 1985 *J Acoust Soc Am*

- Could we explain the performance effects of speech in such the terms of engineering so that these findings could benefit noise control in open-plan offices?
Background

Frontzcac et al, *Indoor Air* 2012

52,920 occupants in 351 buildings

U.S. Offices

2000-2010
STI

- STI can be reduced by
  - reducing speech-to-noise ratio
    - Increasing background level
  - Reducing speech level
  - increasing reverberation time (EDT)

<table>
<thead>
<tr>
<th>STI</th>
<th>Speech intelligibility</th>
<th>Speech privacy</th>
<th>Examples in offices</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 ... 0.05</td>
<td>very bad</td>
<td>confidential</td>
<td>Between two single-person office rooms, high sound insulation</td>
</tr>
<tr>
<td>0.05 ... 0.20</td>
<td>bad</td>
<td>good</td>
<td>Between two single-person office rooms, normal sound insulation</td>
</tr>
<tr>
<td>0.20 ... 0.40</td>
<td>poor</td>
<td>reasonable</td>
<td>Between workstations in a high-level open-plan office</td>
</tr>
<tr>
<td>0.40 ... 0.60</td>
<td>fair</td>
<td>poor</td>
<td>Between desks in a well designed open-plan office</td>
</tr>
<tr>
<td>0.60 ... 0.75</td>
<td>good</td>
<td>very poor</td>
<td>Between desks in an open-plan office, reasonable acoustical design</td>
</tr>
<tr>
<td>0.75 ... 0.99</td>
<td>excellent</td>
<td>no</td>
<td>Face-to-face discussion, good meeting rooms</td>
</tr>
</tbody>
</table>

Early decay time $T[s]$
Review of experimental work prior to 2004

Hongisto 2005 Indoor Air

Data points from 32 experiments reviewed

WHAT HAPPENS HERE THEN?

Speech Transmission Index STI

Change in performance DP [%]
Alternatives of functional shapes

Change in performance [%]

-8 -7 -6 -5 -4 -3 -2 -1 0 0.00 0.20 0.40 0.60 0.80 1.00

Speech Transmission Index STI

-8 -7 -6 -5 -4 -3 -2 -1 0 0.00 0.20 0.40 0.60 0.80 1.00

Linear
Ramp
Exponential
Logarithmic
Sigmoidal
Dependence of subj. intelligibility on STI

Subjective speech intelligibility [% correctly heard]

Speech Transmission Index, STI

- Phonetically balanced (PB) words
- Consonant-vocal-consonant (CVC) syllables
- Sentences

Hongisto 2005 *Indoor Air*
Original model

- Hypothetic model
  - Speech intelligibility vs. STI curve is applied for performance loss
  - Various task types are combined
  - Lack of data
- Perfect performance when STI below 0.20
- Max. performance loss is achieved when 0.50
Recent update

Jahncke, Hongisto, Virjonen 2012 Appl Acoust
Recent experimental work

- More or less support has been given to the model
  - Keus van de Poll 2014 *Appl Acoust*
  - Ebissou et al. 2015 *Appl Acoust*
  - Jahncke et al. 2012 *Appl Acoust*
  - Schlittmeier and Liebl 2015 *Facilities*
  - Hongisto et al. 2015 (*Published in Finnish*)

- A more general model also exists
  - Schlittmeier et al. 2012 *Atten Percept Psychophys*
  - Working memory performance as a function of fluctuation strength

- True shape may not be sigmoidal but steeper
- The exact form of the model may never be found
  - Type of task, type of speech, other factors
- Nevertheless, the detriments of irrelevant speech can be controlled by reducing STI
Application

- STI was could be proven to be such an important objective quantity that it should be measured in open-plan offices
- STI was chosen to **ISO 3382-3:2012**
- STI of normal effort speech is measured as a function of distance, as well as the SPL of speech
- Distraction distance \( r_D \) is the distance where STI falls below 0.50.
Global promotion of noise control

- 2007: ICA preliminary method
- 2008: First national guidelines for rD and D_{25} in Finland
- 2012: ISO 3382-3 in 2012
- 2010: Numbers of cross-sectional studies have emphasized the noise problem in open-plan offices

- Research in the area is still growing – Health aspects have received larger interest
- Business possibilities of acoustic consultancy has increased
- Room acoustic models and measurement apparatus have improved w.r.t. new compact features needed in open-plans
- Material manufacturers disseminate the r&d evidence to improve their business