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Acoustics as a factor of Ergonomics

Communication Behavior and Workload of Pupils and Teachers in Highly Absorbent Classrooms



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Research project

Field Study performed by the
Institute of Interdisciplinary School Research
ISF
Bremen University

Dr. Gerhart Tiesler
Dr. Markus Oberdörster

Acoustic Ergonomics of Schools

2001 - 2006



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Research project



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baua:
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Research at ISF



Institute of Interdisciplinary School Research
ISF

Workload of Teachers
1998-2001

Noise in Educational Institutions
2001 – 2004

Acoustic Ergonomics
of Schools
2001 – 2006

The health and performance implications
of the school environment
2006 - 2008

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Who decides?




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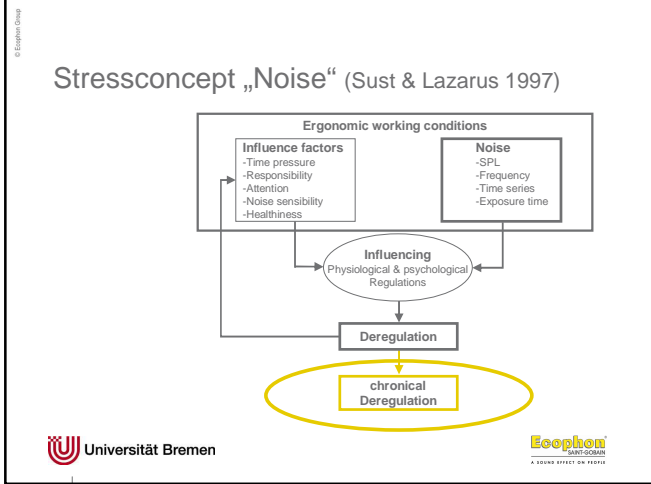
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Transdisciplinäre Approach!



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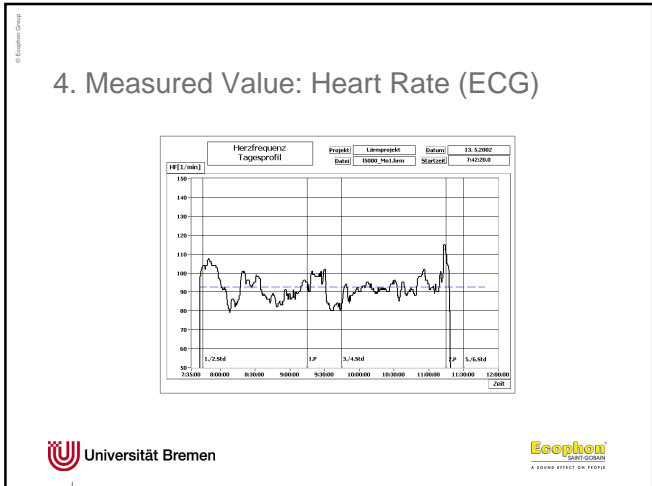
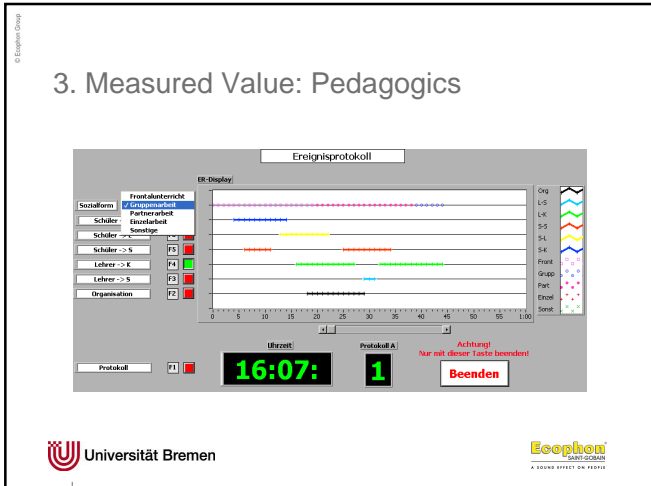
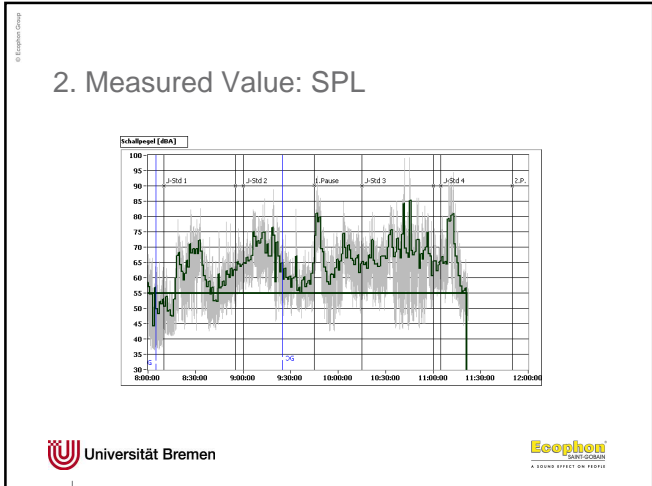
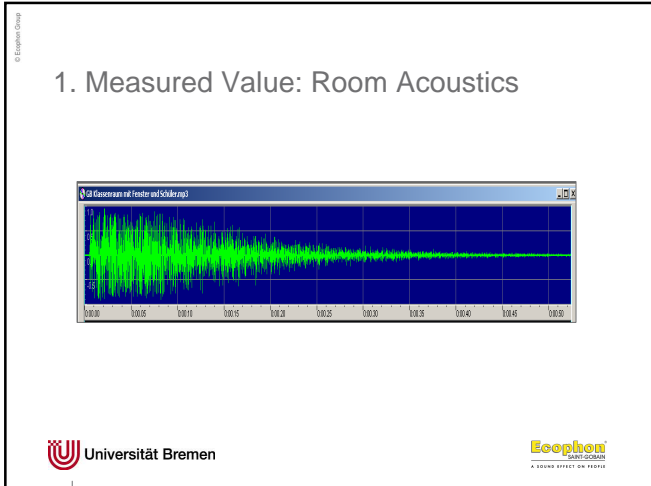


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Project Overview

- 5 involved schools:
 - 1 Primary School in Havixbeck (near Münster) → „Labschool“
 - 2 Primary Schools in Bremen
 - 1 Primary School in Bremerhaven
 - 1 High School Center in Bremen (Haupt-, Realschule, Gymnasium) → „Fieldschool“
- 28 involved classes from 1st to 10th grade (1 week each)
- 575 observed lessons

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Database

Teaching Reality

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„Modern“ Teaching ?!

9

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„Modern“ Teaching ?!

- Openness
- Independence
- Individualisation

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How to measure Teaching?

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How to measure Teaching?

„Lesson - Grid“

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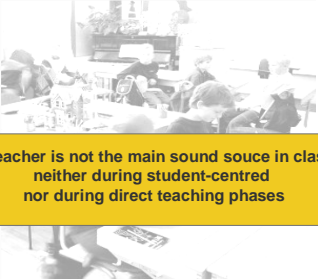
How to measure Teaching?

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a first surprise






The teacher is not the main sound source in class – neither during student-centred nor during direct teaching phases

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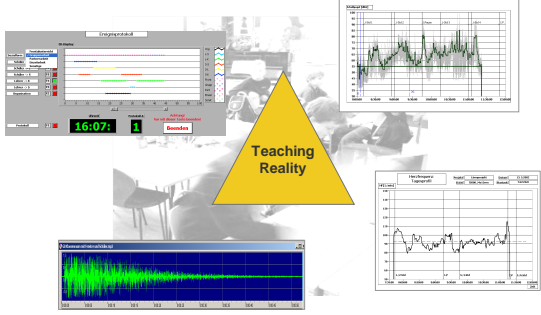


Results

1. Room Acoustics
2. SPL Analysis
3. Pedagogical Relevance
4. Workload & „Acoustic Ergonomics“

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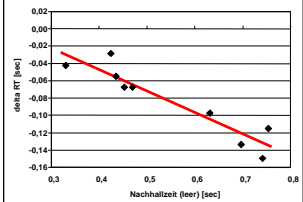
1.) Room Acoustics

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1.) Room Acoustics



Variance of RT depending on occupation of classroom
Full filling of the classroom compared with empty room



$$\text{delta RT}[\text{sec}] = 0,052 - 0,249 \cdot \text{RT} [\text{sec}]$$

$$r = 0,94$$

Database:
all classrooms
Labschool and
Fieldschool
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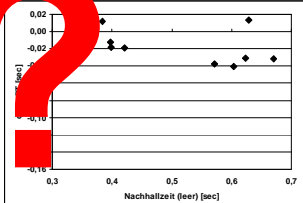



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1.) Room Acoustics

Variance of RT depending on occupation of classroom
Full filling of the classroom compared with half-filled room

Influence of occupation becomes neglectable after the first approx. 10 pupils

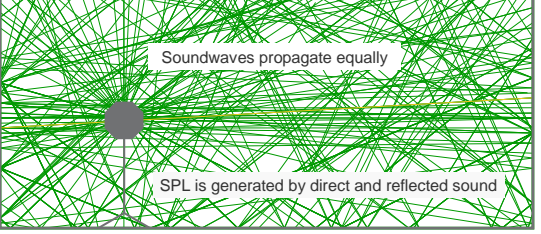


Database:
all classrooms
Labschool and
Fieldschool
© 2005



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Keyword: Diffusivity



Soundwaves propagate equally

SPL is generated by direct and reflected sound

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Keyword: Diffusivity

vertical soundwaves are absorbed by the ceiling

SPL is generated by direct and **reduced** reflected sound

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Keyword: Diffusivity

vertical sound energy is reduced very quickly

horizontal sound energy remains much longer in the room !

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Sound field structure in partly diffuse rooms

Non-grazing sound field

Grazing sound field

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Sound field structure in partly diffuse rooms

Π_{ng}

E_{ng}

$\Pi_{ng,d}$

$\Pi_{ng,g}$

E_g

Π_g

$\Pi_{g,d}$

Nilsson, E.: Decay Processes in Rooms with non-diffuse Sound Fields

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Influencing factors

Non-grazing sound field

Grazing sound field

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Influencing factors

Non-grazing sound field

Grazing sound field

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Influencing factors

Non-grazing sound field Grazing sound field

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Room Acoustics = T60?

Example:
classroom near Kassel
very low wall diffusion

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

125 Hz 250 Hz 500 Hz 1 kHz 2 kHz 4 kHz

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Room Acoustics = T60?

Example:
classroom near Kassel
"improved" wall diffusion

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

125 Hz 250 Hz 500 Hz 1 kHz 2 kHz 4 kHz

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short:

"Non-grazing sound field" "Grazing sound field"

Angle of incidence ca. 10 - 90 °/ceiling Angle of incidence < 5 - 10°/ceiling

main influencing factor: ceiling main influencing factors: wall (& furniture)

Determines Sound Pressure Level Determines Reverberation Time

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2.) SPL Analysis

Teaching Reality

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2.) SPL Analysis

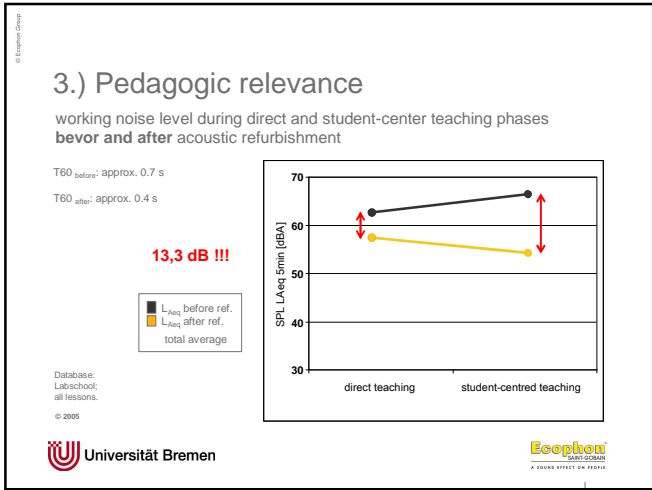
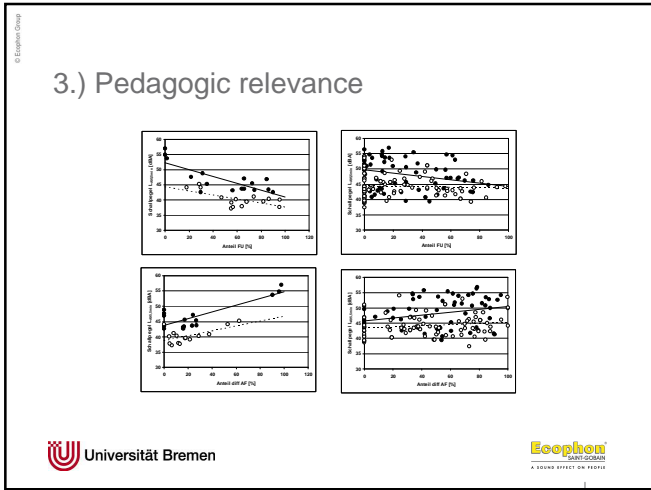
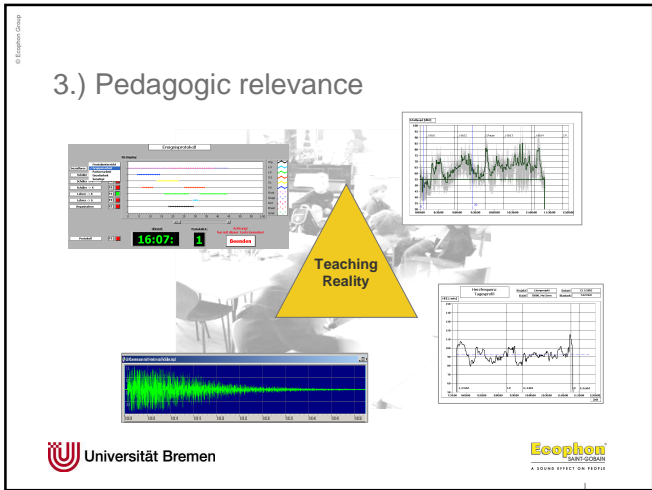
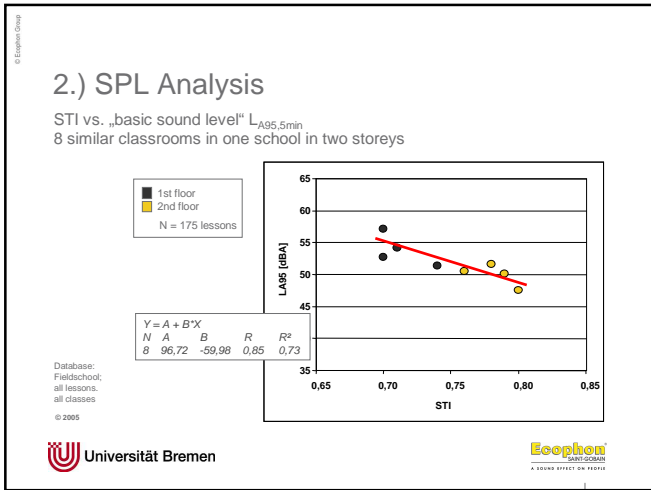
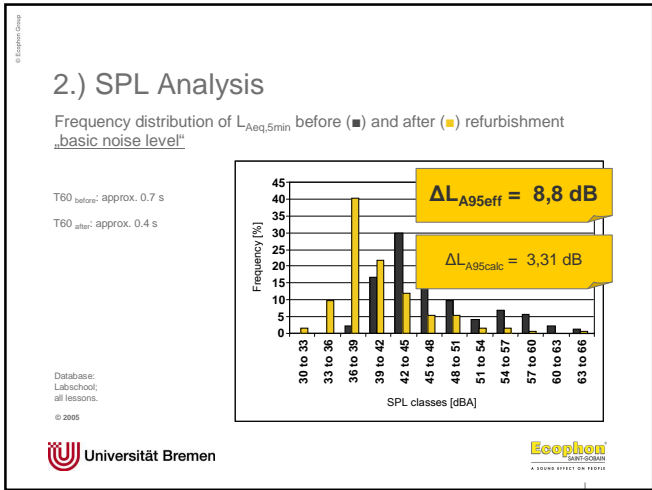
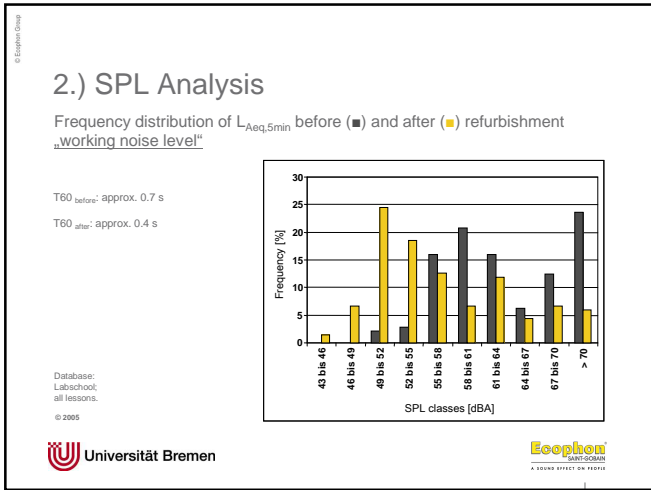
Original SPL recording [dB(A)] during a typical school morning

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30

08:00 08:20 08:40 09:00 09:20 09:40 10:00 10:20 10:40 11:00 11:20 11:40 12:00

1.: Math/ incl. silent work phase 2.: Language/ silent work 3.: empty classroom 4.: Language/ silent work

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4.) Workload & „Acoustic Ergonomics“

Teaching reality

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Noise as a factor of strain

ISF Study 1999 Report of questionnaire about workload of teachers
„concerning the students i am primarily stressed by...“
[105] ... noise, made by students.“

Database:
N = 1159
© 1999

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Workload Reaction

Example: SPL and HR_{5min} of a female teacher

Database:
Labschool;
all lessons;
of one school day
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Teachers Health

Single Case Example: Stress reaction of a female teacher; Tue 2nd lesson

Database:
Labschool;
2 lessons
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Teachers Health

Basic activation under different acoustic conditions (Labschool)

Database:
Labschool;
12 lessons
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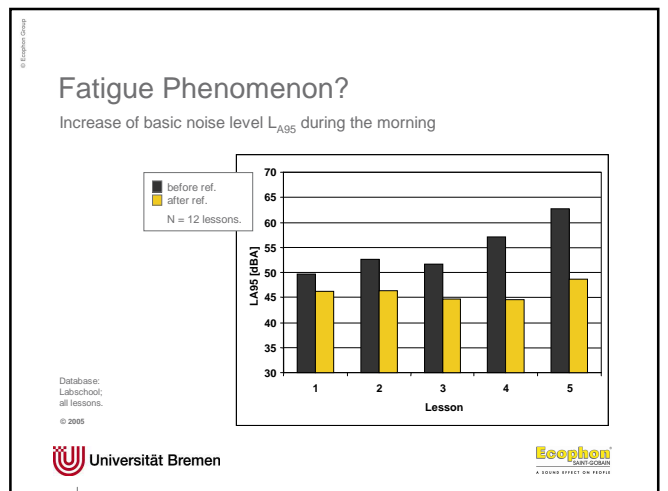
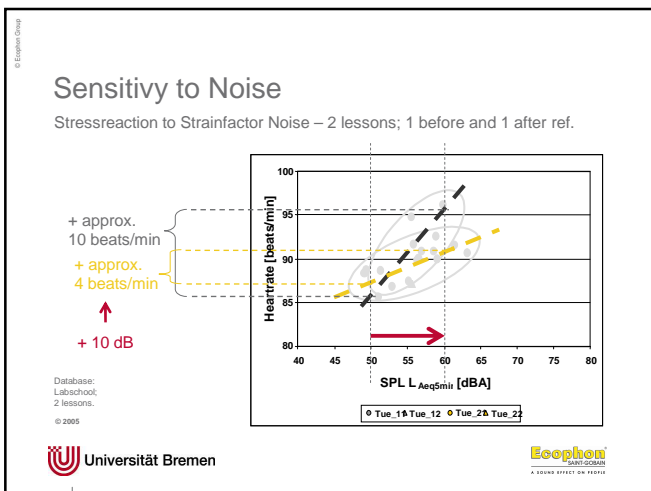
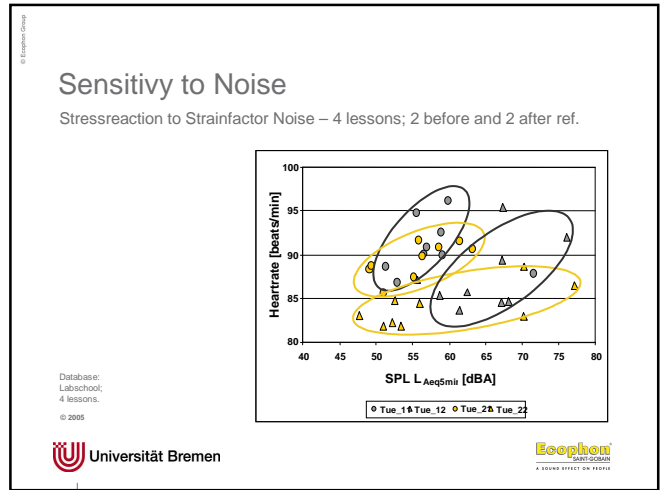
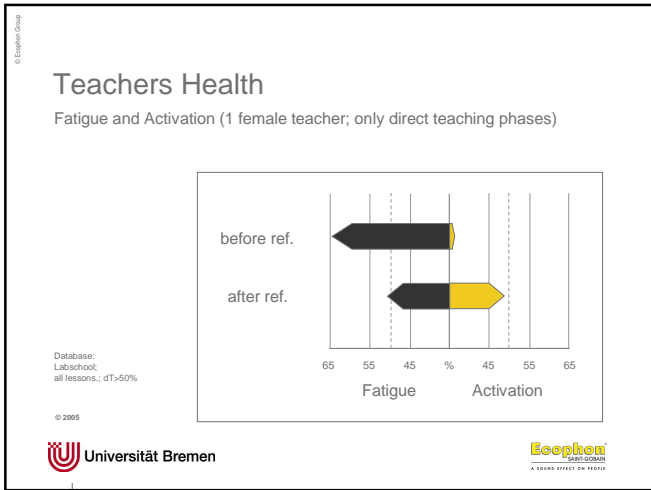
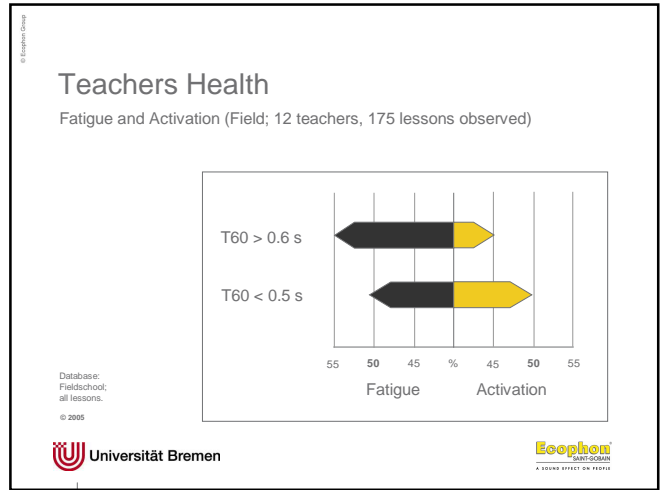
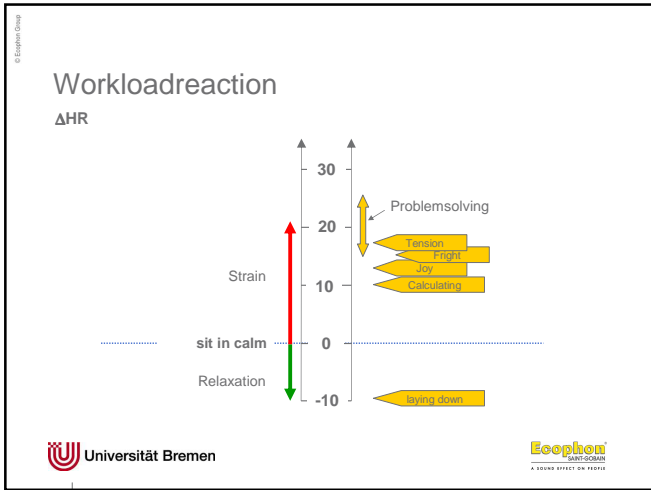
Teachers Health

Basic activation under different acoustic conditions (Fieldschool)

Database:
Fieldschool;
all lessons
© 2005


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So, what happens:



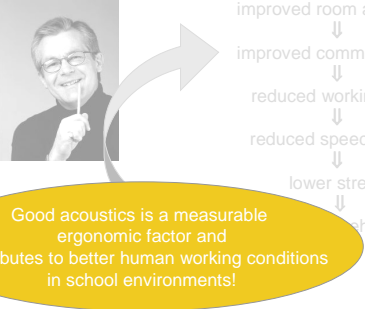
- improved room acoustics
- ↓
- improved communication
- ↓
- reduced working SPL
- ↓
- reduced speech effort
- ↓
- lower stress
- ↓
- change of behaviour

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So, what happens:



- improved room acoustics
- ↓
- improved communication
- ↓
- reduced working SPL
- ↓
- reduced speech effort
- ↓
- lower stress
- ↓
- change of behaviour


Good acoustics is a measurable ergonomic factor and contributes to better human working conditions in school environments!

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Thanks for your attention!



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