SAFE (Sound acoustics for employees)

Experts meeting
November 2015
at the BAuA in Dortmund

Psychoacoustics and health – The importance of psychoacoustics and its relation to noise effects

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Introduction

- The existence of noise effects leading to adverse health effects is beyond controversy

- However, the main factors responsible for specific (non-auditory) noise effects are still not clear

Noise Health Effects

- *Currently, the recommended practice is to assume that the equal energy principle is approximately valid for most types of noise and that a simple $L_{Aeq,T}$ measure will indicate the expected effects of the noise reasonably well.**

→ Is the prediction accuracy of the L_{Aeq} sufficient?

→ What are the limits of the L_{Aeq} indicator?

*World Health Organization (1999). Guidelines for community noise, Ed. Berglund, B., Lindvall, T., Schwela. H.D.

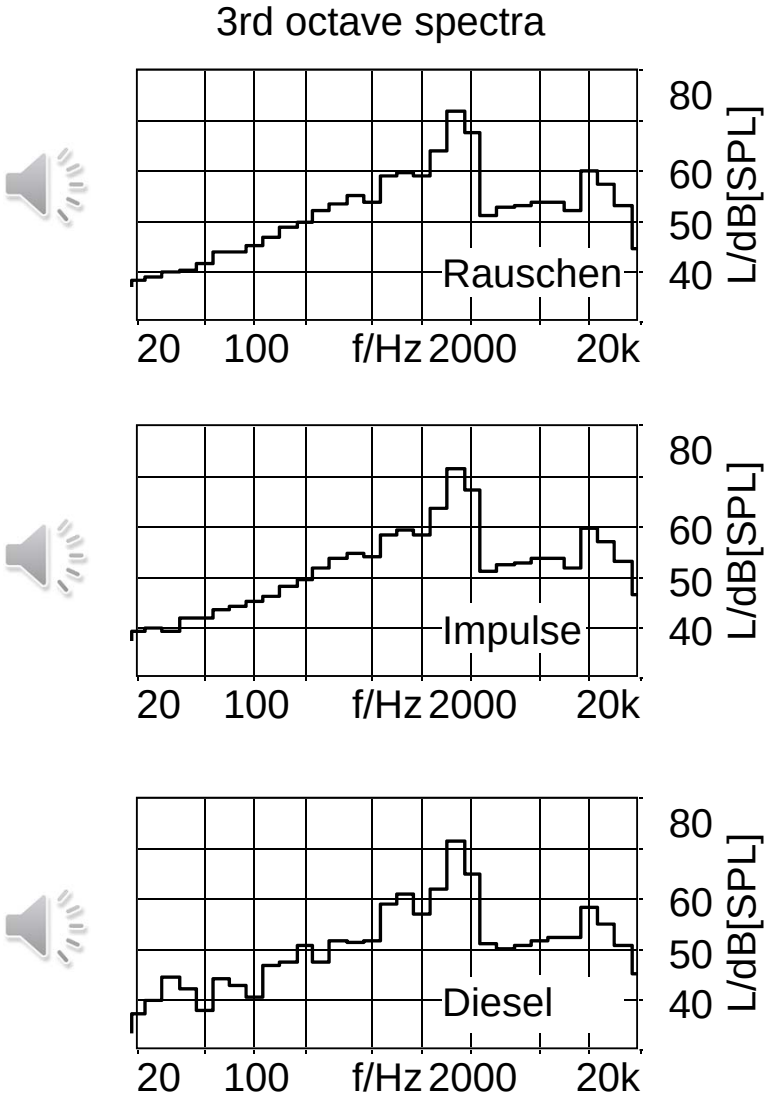
Is the Sound Pressure Level Sufficient?

Almost identical
3rd octave spectra and
overall SPL

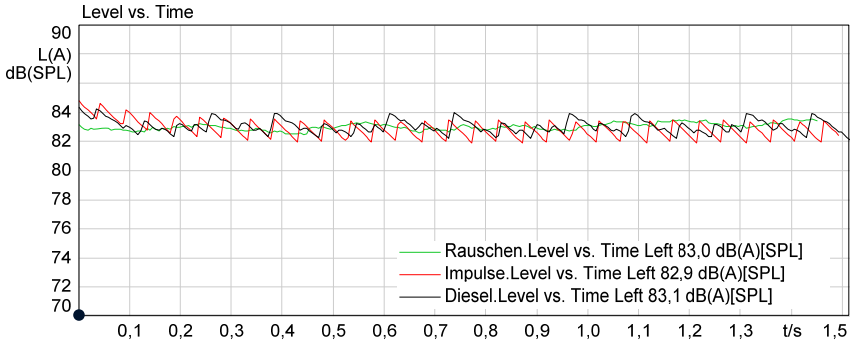
Different auditory sensations

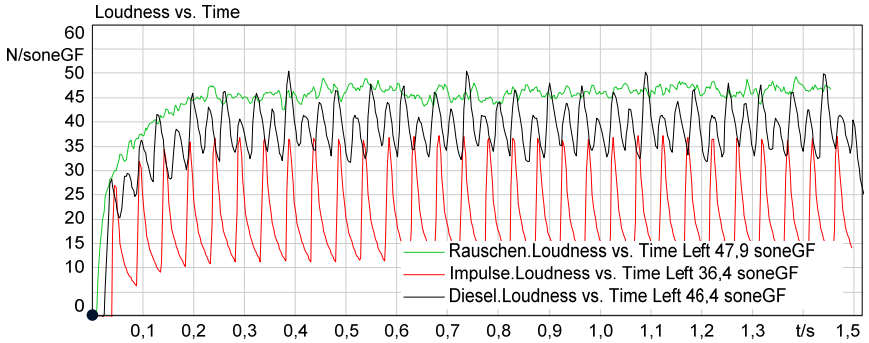
Different psychological effects?

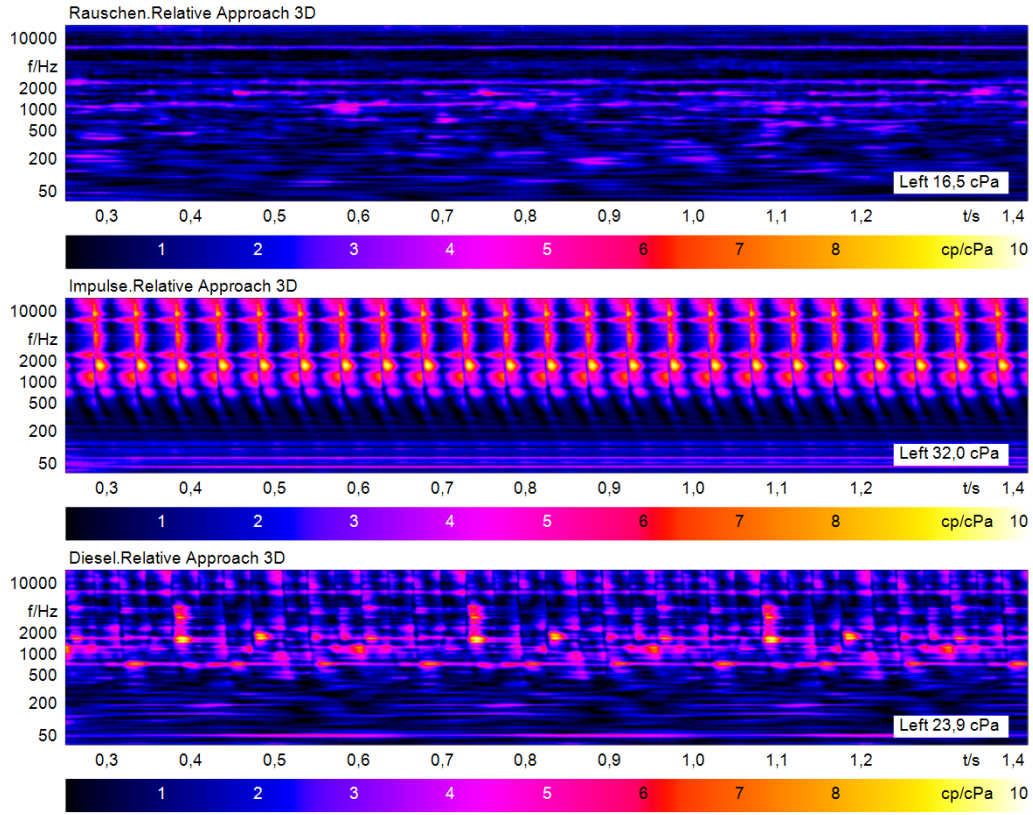
Different physiological reactions?



Human Signal Perception



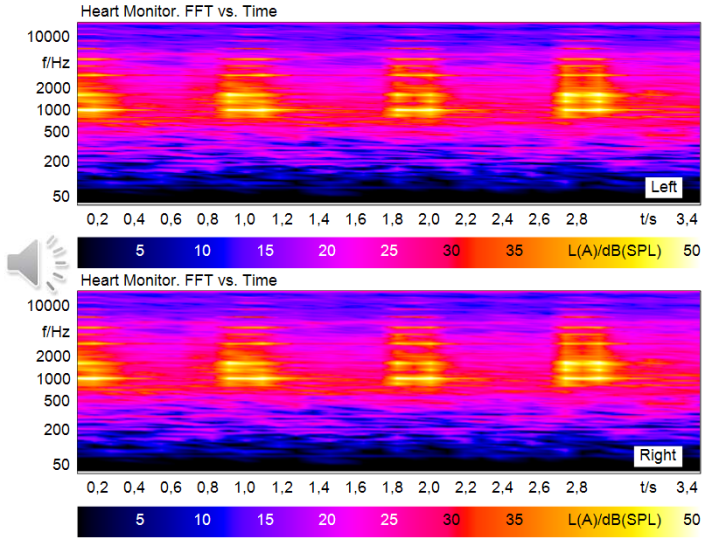




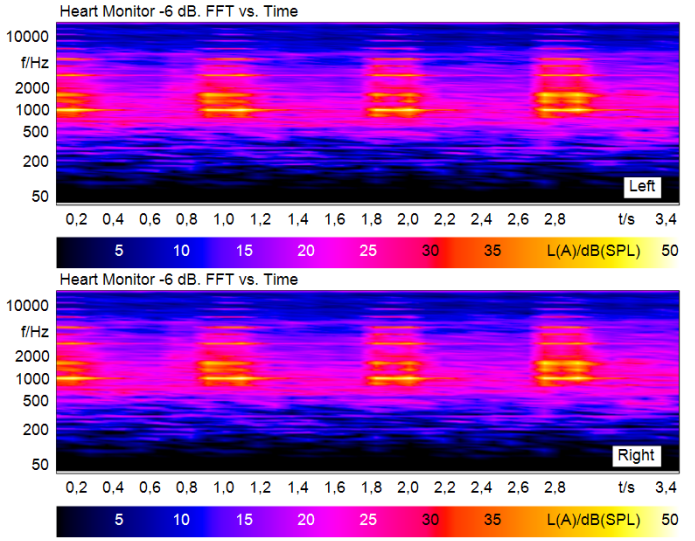
- Relative Approach Analysis as a pattern recognition algorithm quantifying perceivable patterns largely ignoring steady-state noise components

*Genuit, K. (1996). Objective evaluation of acoustic quality based on a relative approach, Internoise 1996, Proceedings, Liverpool, UK

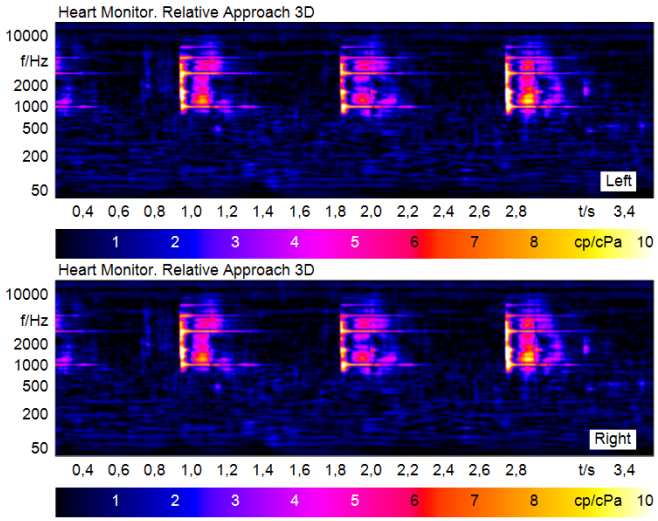
Overall Sound Pressure Level vs. Noise Patterns



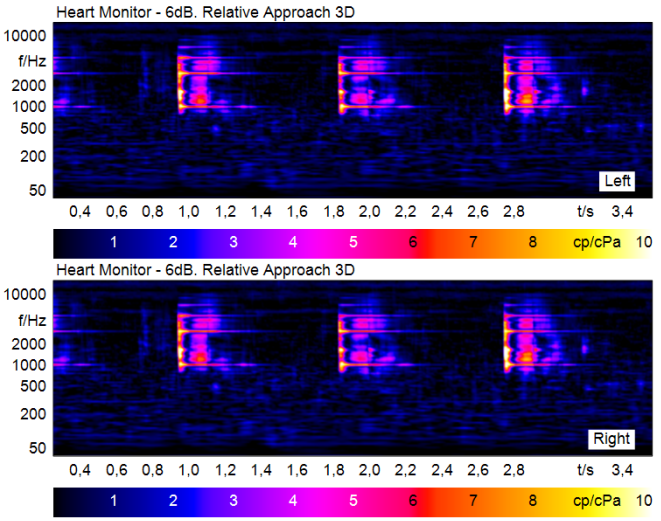
- 6dB



How does the sound and its pattern strength change?



- 6dB



Can annoyance be reduced by masking patterns by less attention-attracting noise?

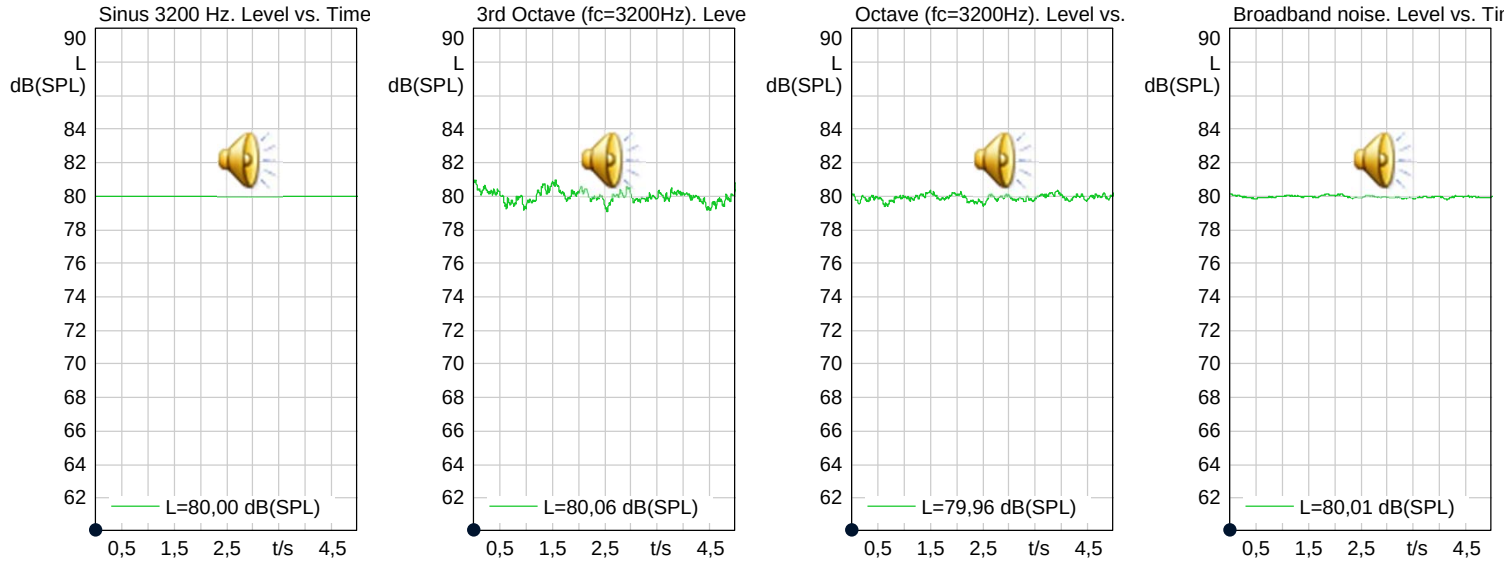
Preliminary Conclusions

- Certain signal properties due to their perceptual prominence attract automatically attention
  - Informational content
  - Patterns in the time and frequency domain
    - Tones
    - Transient noises
    - Unpredictable unsteadiness
- In particular, employees in office context are distracted by specific signal properties beyond the absolute SPL → cognitive load
  - Reduction of performance and concentration
  - Increase of fatigue effects

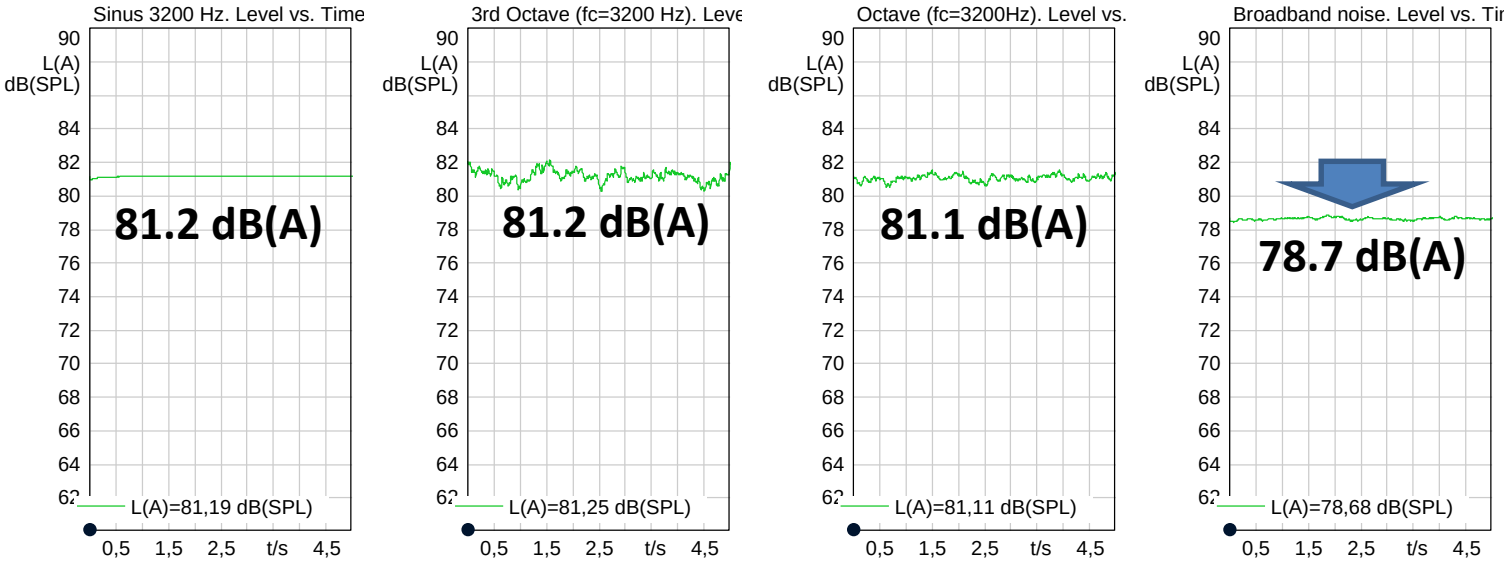
Physiological Responses to Synthetic Noises with Constant Sound Pressure Level

Jansen, G., Rey, P.Y. (1962). Der Einfluss der Bandbreite eines Geräusches auf die Stärke vegetativer Reaktion. In: European Journal of Applied Physiology, Vol. 19. Berlin, Heidelberg: Springer Verlag

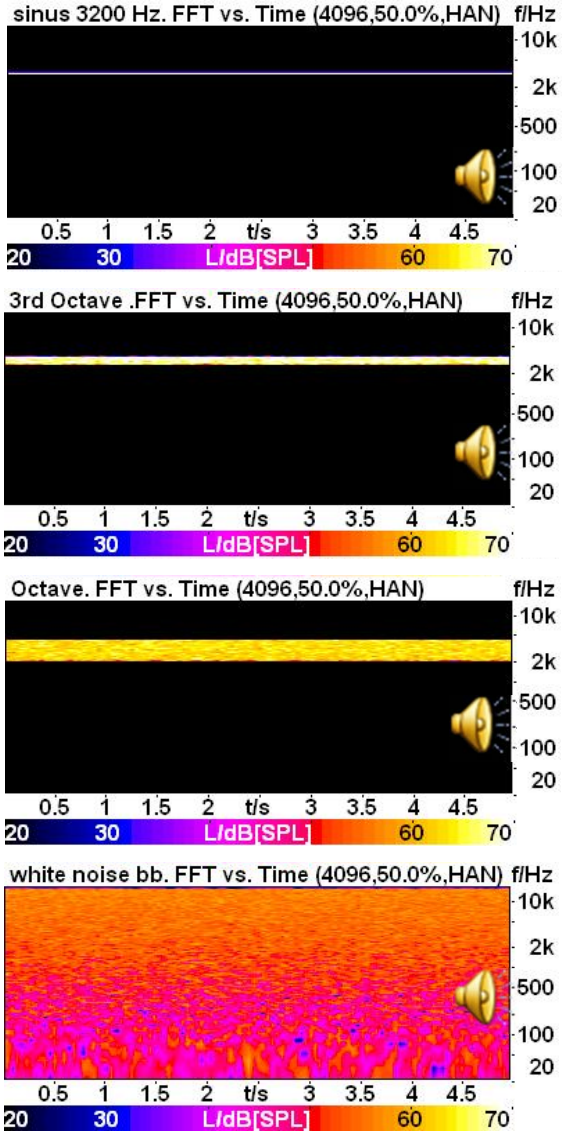
Four Sounds with Constant Sound Pressure Level

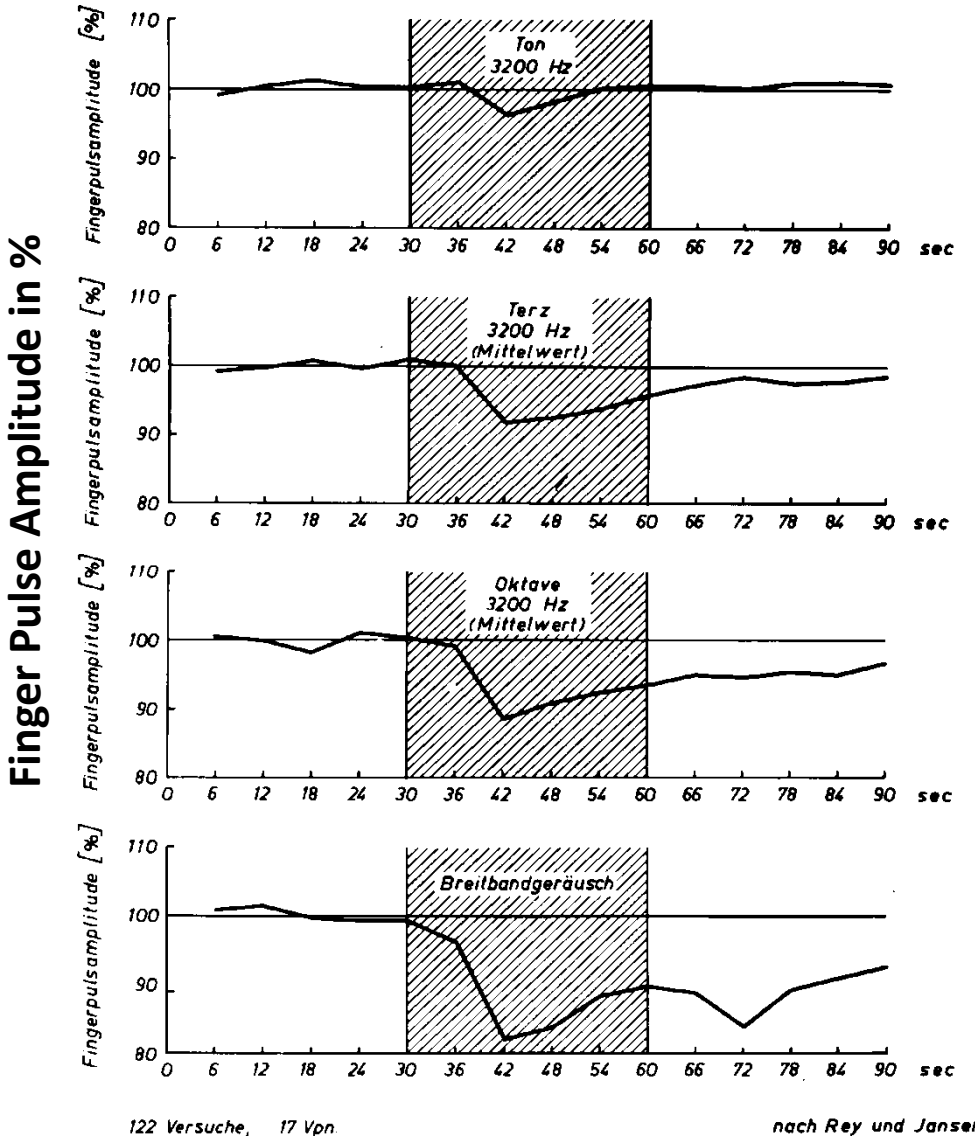


80 dB(SPL)



Reaction to Noise – Is Sound Pressure Level Sufficient?



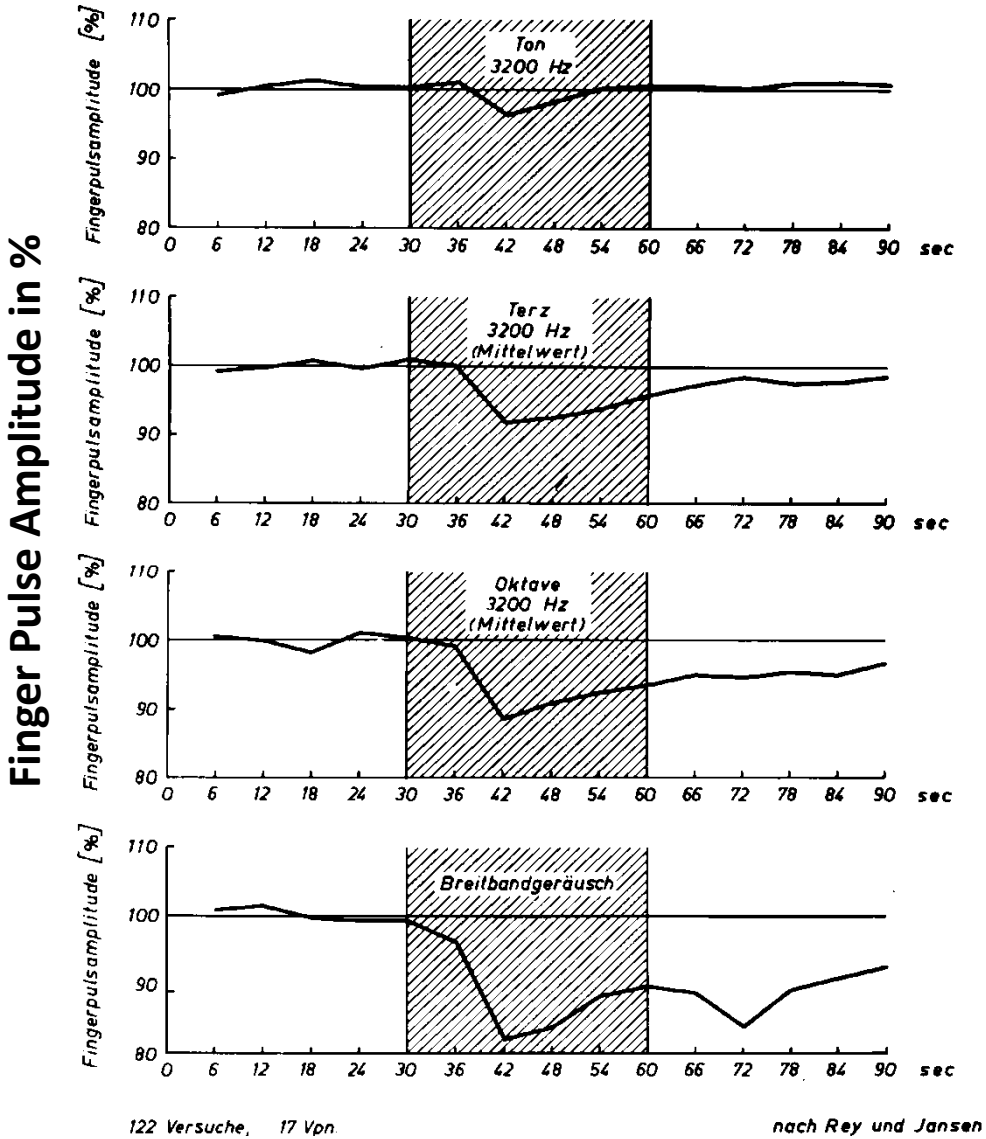


Jansen, G., Rey, P.Y. (1962). Der Einfluss der Bandbreite eines Geräusches auf die Stärke vegetativer Reaktion. In: European Journal of Applied Physiology, Vol. 19. Berlin, Heidelberg: Springer Verlag

FPA as a measure of the peripheral blood circulation

Reaction to Noise – Is Sound Pressure Level Sufficient?

- The different evoked physiological reactions cannot be explained on the basis of the equal energy principle



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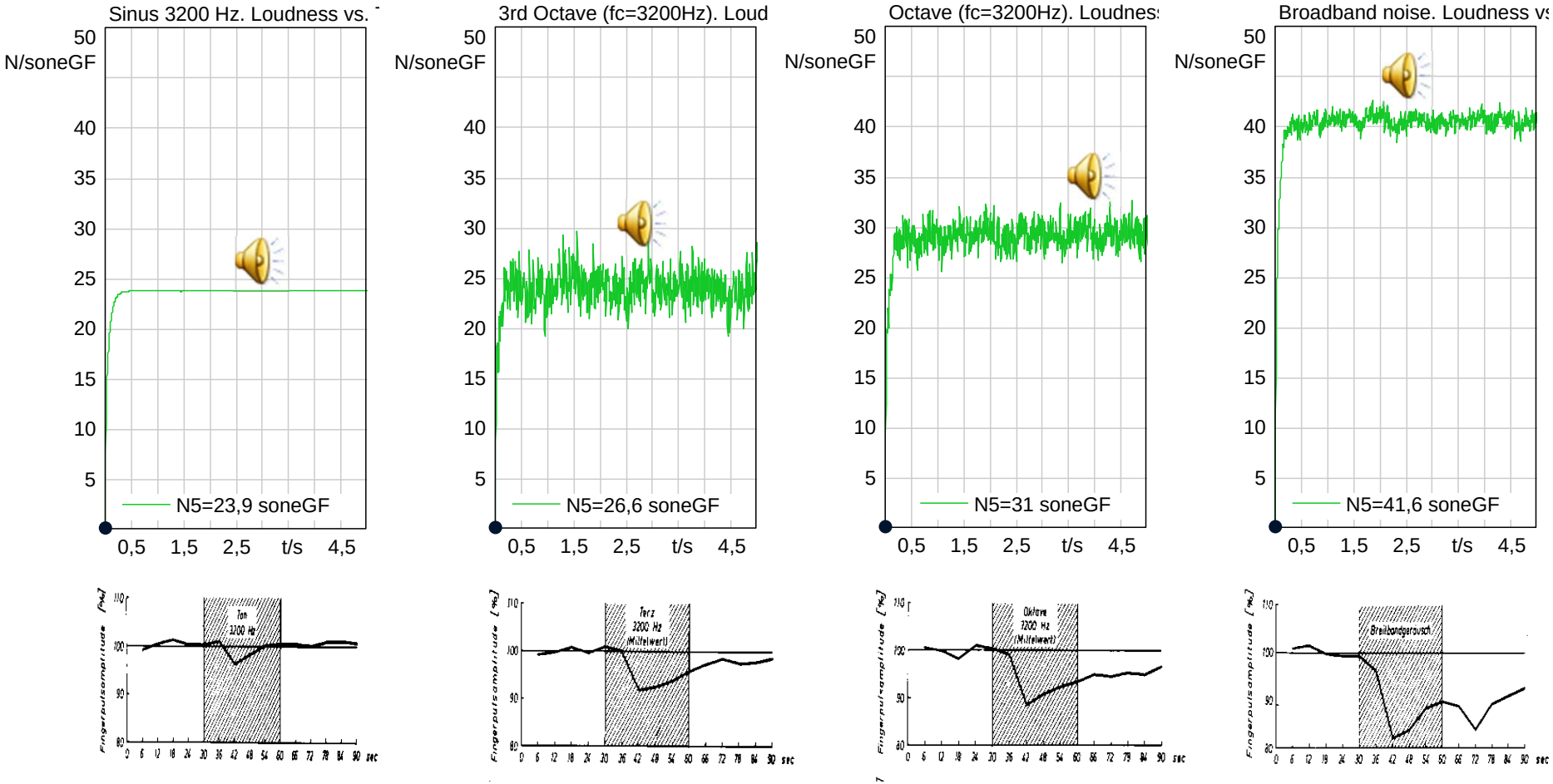
Reaction to Noise – Is Sound Pressure Level Sufficient?

Analysis of loudness according to **DIN 45631/A1**



- Consideration of sound pressure level is not sufficient – psychoacoustic loudness needed?

Physiological Responses to Industrial Noises with Constant Sound Pressure Level

Jansen, G., Gros, E. (1986). Non-auditory Effects of Noise: Physiological and Psychological Effects, In: Saenz, A.L., Stephens, W.B. (eds.) Noise Pollution, John Riley

Technical Noises and Their Influence on Physiological Responses

Broad-band noise

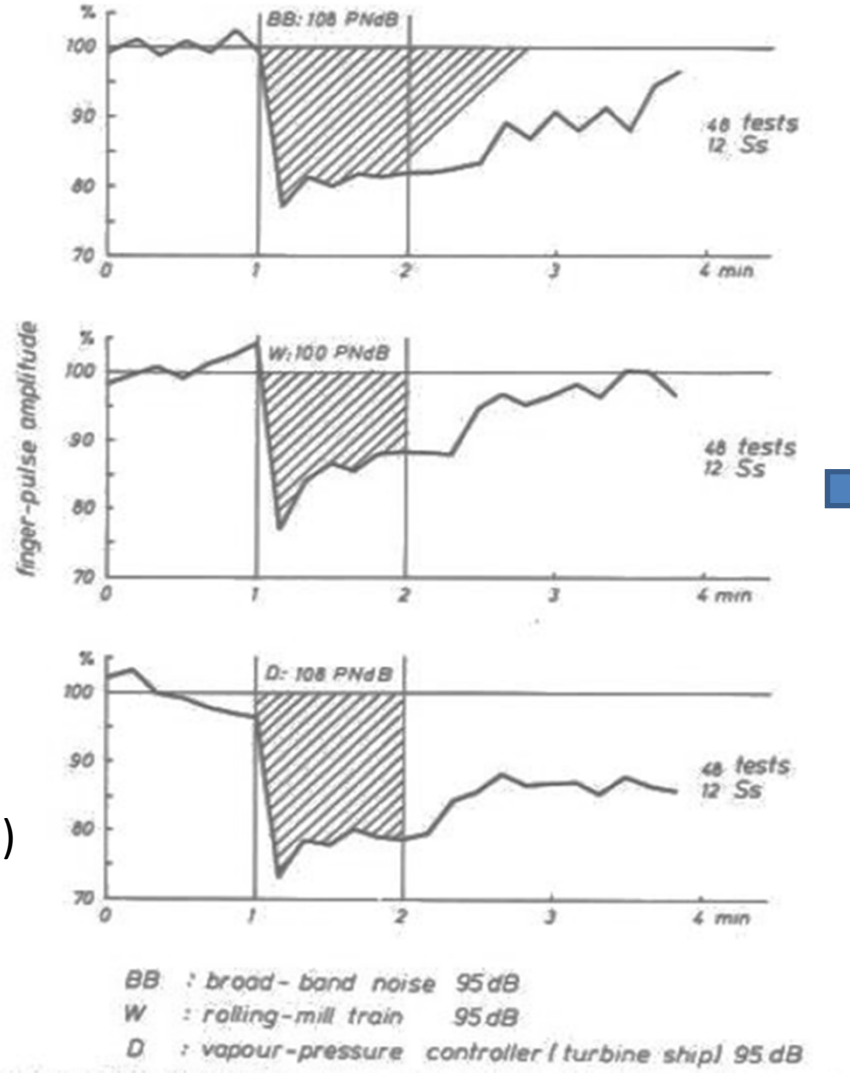
95dB

Rolling-mill train

95dB

Vapour-pressure controller (turbine ship)

95dB



Different vegetative responses evoked

Jansen, G., Gros, E. (1986). Non-auditory Effects of Noise: Physiological and Psychological Effects, In: Saenz, A.L., Stephens, W.B. (eds.) Noise Pollution, John Riley

Physiological Responses to Road Traffic Noises with Constant Sound Pressure Level

Klein, A. (2010). Untersuchungen zum Einfluss vereinzelt auftretender Hörereignisse auf die Bewertung komplexer Geräuschszenarien, bachelor thesis, Oldenburg, Herzogenrath

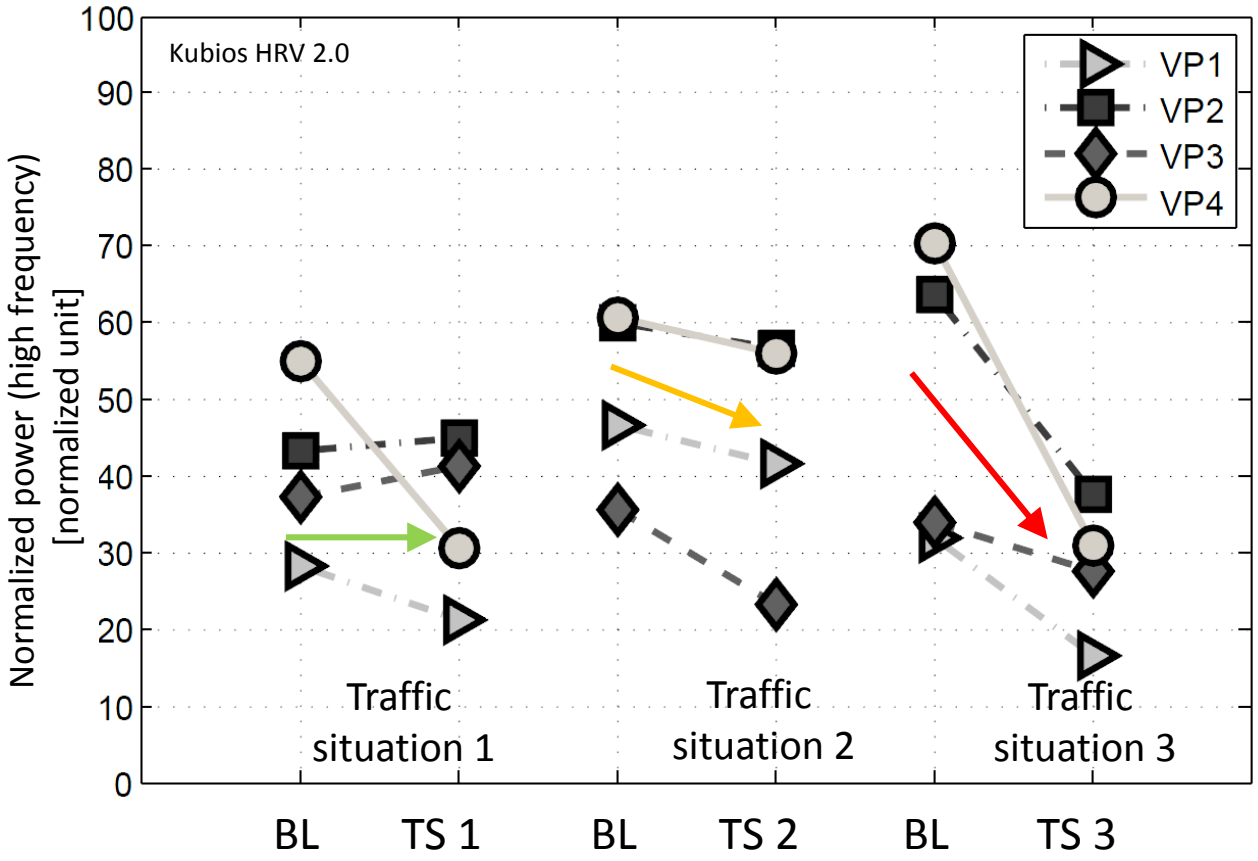
Physiological Responses to Traffic Noise*

- Test track measurements to control road traffic
- 650 vh/h and 11% share of heavy vehicles
- Same road surface for all samples
- 8 minutes of different
  - *Traffic situation 1*
  - *Traffic situation 2*
  - *Traffic situation 3*

} approx. L_{Aeq} = 69 dBA

- Randomized playback

Physiological Responses to Traffic Noises



- Traffic situation 3 caused strongest reactions (parasympathetic activity)

(HF: 0.15 - 0.4 Hz)

Influence of Sound Character on Physiological Reactions

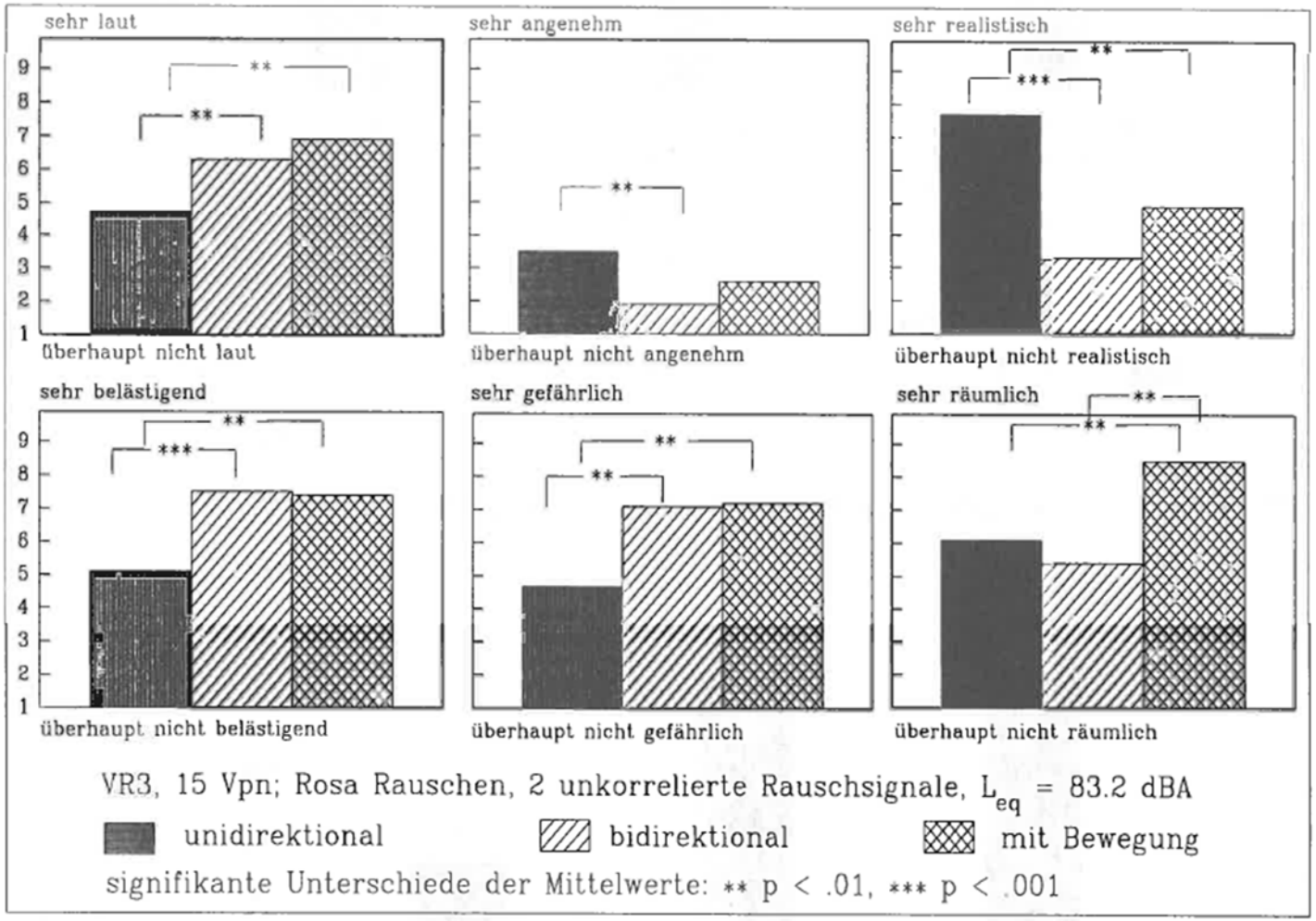
	Traffic situation 1	Traffic situation 2	Traffic situation 3
L_{Aeq}	69.0 dBA	69.3 dBA	69.7dBA
N_5 according to DIN45631/A1	30.1 sone	33.3 sone	33.1 sone
N_{ave} according to DIN45631/A1	16.1 sone	16.7 sone	19.0 sone
Sharpness S according to Aures	1.98 acum	2.07 acum	2.42 acum
Relative Approach (T&F)	7.0 cpa	7.25 cpa	8.2 cpa

- Obviously, the character of noise can influence physiological reactions to a certain extent

Assessments of Synthetic Noises Varying in Direction of Sound Incidence with Constant Sound Pressure Level

Genuit, K., Blauert, J., Bodden, M., Jansen, G., Schwarze, S., Mellert, V., Remmers, H. (1997). Entwicklung einer Messtechnik zur physiologischen Bewertung von Lärmeinwirkungen unter Berücksichtigung der psychoakustischen Eigenschaften des menschlichen Gehörs, Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

Meaning of Binaural Listening on Assessments



- Assessments of loudness, pleasantness, annoyance, threat are significantly influenced by the position of sources

Genuit, K., Blauert, J., Bodden, M., Jansen, G., Schwarze, S., Mellert, V., Remmers, H. (1997). Entwicklung einer Messtechnik zur physiologischen Bewertung von Lärmeinwirkungen unter Berücksichtigung der psychoakustischen Eigenschaften des menschlichen Gehörs, Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

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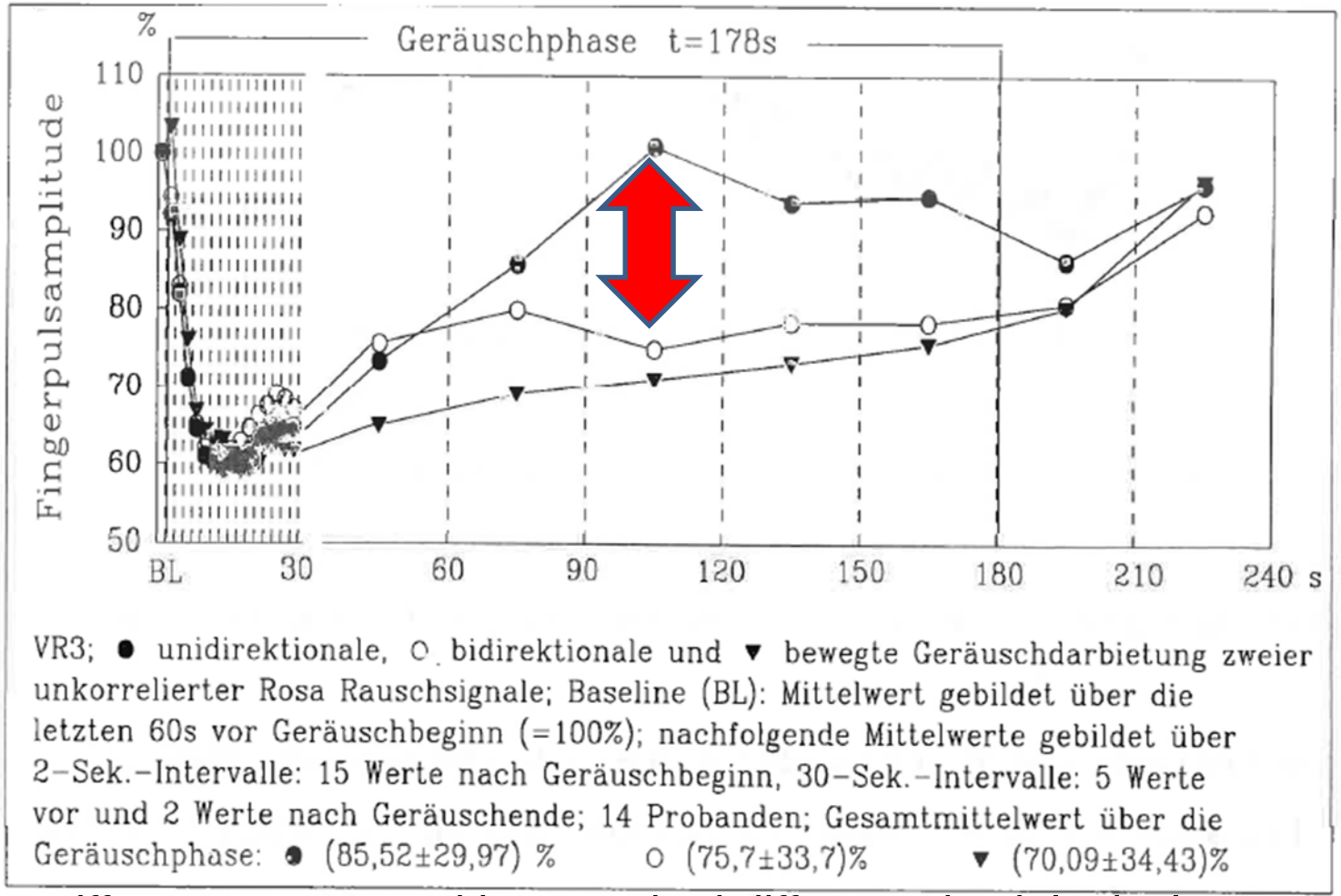
Meaning of Binaural Listening on FPA



VR3; ● unidirektionale, ○ bidirektionale und ▼ bewegte Geräuschdarbietung zweier unkorrelierter Rosa Rauschsignale; Baseline (BL): Mittelwert gebildet über die letzten 60s vor Geräuschbeginn (=100%); nachfolgende Mittelwerte gebildet über 2-Sek.-Intervalle: 15 Werte nach Geräuschbeginn, 30-Sek.-Intervalle: 5 Werte vor und 2 Werte nach Geräuschende; 14 Probanden; Gesamtmittelwert über die Geräuschphase: ● (85,52±29,97) % ○ (75,7±33,7)% ▼ (70,09±34,43)%

- Different source positions evoked different physiological responses
- Spatial hearing plays an important role for physiological reactions and annoyance

Genuit, K., Blauert, J., Bodden, M., Jansen, G., Schwarze, S., Mellert, V., Remmers, H. (1997). Entwicklung einer Messtechnik zur physiologischen Bewertung von Lärmeinwirkungen unter Berücksichtigung der psychoakustischen Eigenschaften des menschlichen Gehörs, Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

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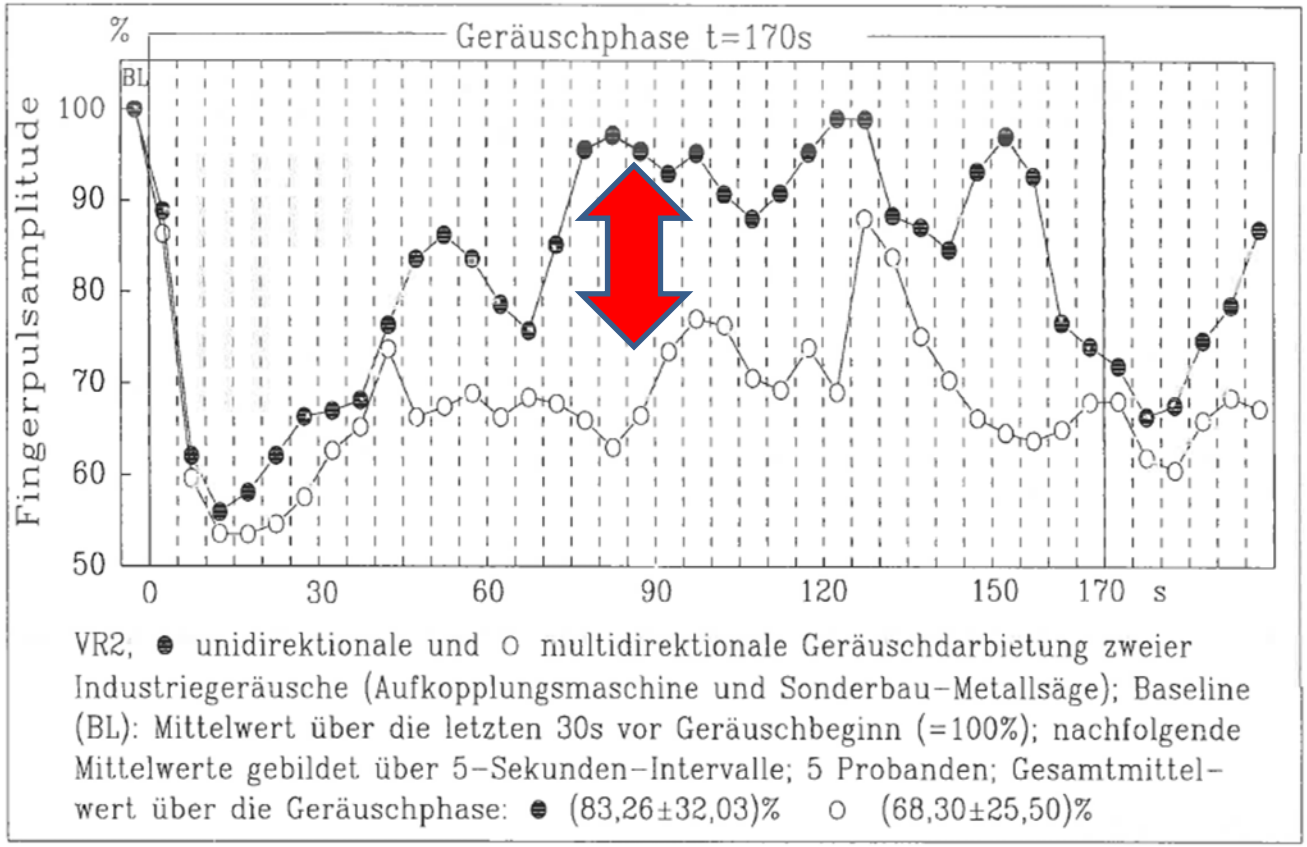
Meaning of Binaural Listening on FPA

- A study investigated the influence of direction of sound incidence on physiological reactions and loudness evaluation



VR2; ● unidirektionale und ○ multidirektionale Geräuschdarbietung zweier Industriegeräusche (Aufkopplungsmaschine und Sonderbau-Metallsäge); Baseline (BL): Mittelwert über die letzten 30s vor Geräuschbeginn (=100%); nachfolgende Mittelwerte gebildet über 5-Sekunden-Intervalle; 5 Probanden; Gesamtmittelwert über die Geräuschphase: ● (83,26±32,03)% ○ (68,30±25,50)%

Genuit, K., Blauert, J., Bodden, M., Jansen, G., Schwarze, S., Mellert, V., Remmers, H. (1997). Entwicklung einer Messtechnik zur physiologischen Bewertung von Lärmeinwirkungen unter Berücksichtigung der psychoakustischen Eigenschaften des menschlichen Gehörs, Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

Conclusions

- Physiological reactions and psychological effects are influenced by signal properties beyond the sound pressure level (*in particular for mentally stressful tasks like in office context*)
  - **Spatial distribution of sources** influence physiological reactions and annoyance
  - **Loudness** correlates with physiological reactions and annoyance
  - **Noise character** (like sharpness, patterns, impulsiveness) correlates with physiological reactions and psychological effects
  - **Fluctuations** of noise causes stronger reactions compared to steady-state noise*
- Noise at workplaces with sound pressure levels uncritical regarding hearing impairment, can nevertheless be critical with respect to non-auditory effects and workplace accidents

* Psychological effects are greatest when noise is intermittent, aperiodic (unpredictable) and uncontrollable. (Glass and Singer, 1972, In: Cone, Hayes: Environmental Problems/behavioral Solutions, Cambridge University Press, 1984)

SAFE (Sound acoustics for employees)

- There is a clear link between character of noise and physiological responses
- Psychoacoustic parameters allow for improved (risk) assessment of noise at workplaces
- Psychoacoustic loudness prevails over sound pressure level indicators regarding prediction of annoyance level
- Fluctuating noise leads to more stress than steady noise (e.g. in case of same L_{Aeq})