The ancient Greeks already knew that there are to sides of „to hear“

ακούειν

Acoustics

Physics
“sounds”

Sensory percepts
“sensations”

acoustic events

Lord Rayleigh 1877

auditory events

von Helmholtz 1870

Paul Nipkow 1884 → Television (*Nipkow* disk)
Valdemar Poulsen 1898 → Telegraphone (tape recorder)
Ernst Ruhmer 1901 → Photographophone (sound-on-film)

Milestone #1:

Robert v. Lieben & Lee de Forest 1910 → Vacuum Triode

radio broadcast since 1920 sound-on-film since 1928
public-address systems with loudspeakers since 1924

Physics | Electrical Engineering | Perception

Electro-Acoustics

→ Milestone #2:

since about 1965:
digital signal processing & recording

Manfred Schroeder, ICA 1968, Tokyo: “Computers in Acoustics”

Physics | Electrical Engineering | Computers | Perception

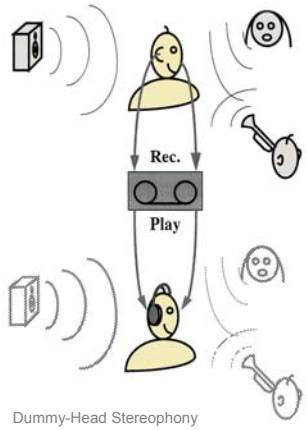
Communication Acoustics

Communication Acoustics

Communication Acoustics represents those areas of acoustics that relate to the modern communication and information sciences and technologies

The Evolution of Communication Acoustics – and its Impact on Room Acoustics

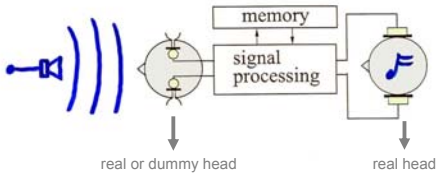
Jens Blauert, D-Bochum



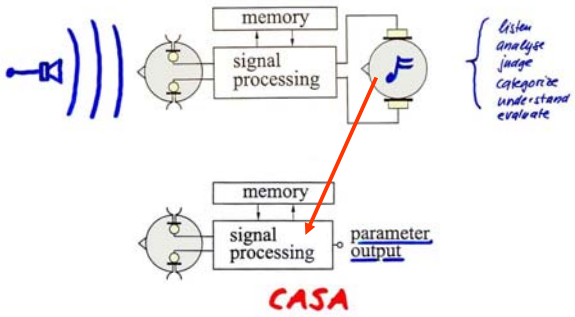
Dummy-Head Stereophony

Binaural Transmission System for Authentic Reproduction

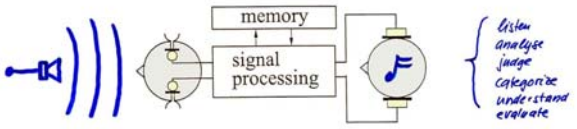
Hudde 1980
Schröter 1983
Pösselt 1986
Els 1986
Xiang 1991



Schematics of a System in Communication Acoustics
for Transmitting Auditory Events Across Space and Time

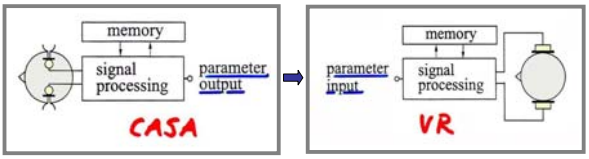


Computational Auditory Scene Analysis



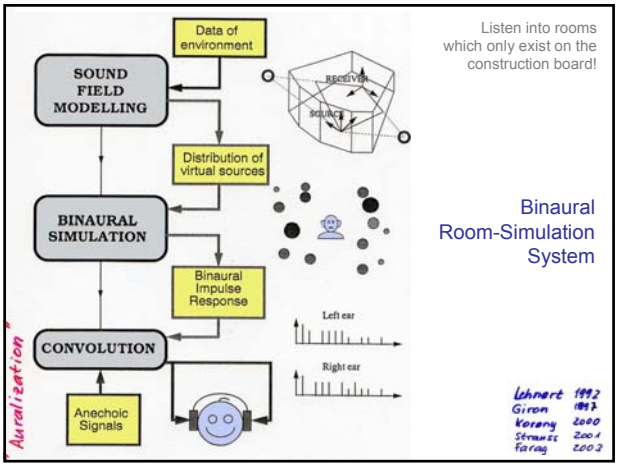
Separation of the Transmission System into Two Parts:

(a) Analysis (b) Synthesis



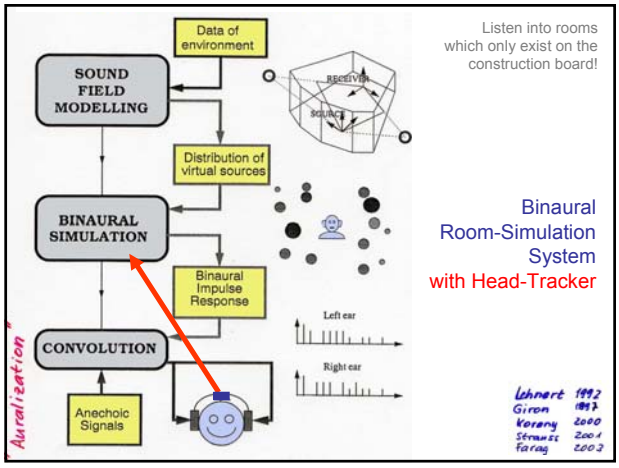
Computational Auditory Scene Analysis Virtual Reality

(a) Virtual Reality
(VR)



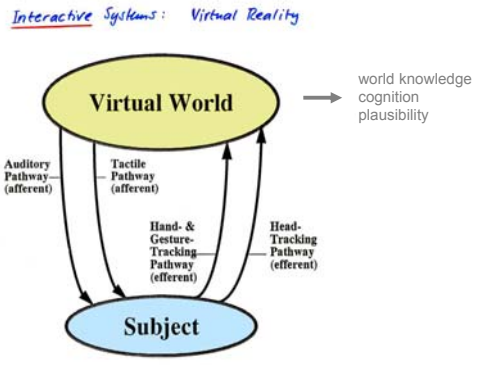
Listen into rooms which only exist on the construction board!

Binaural Room-Simulation System

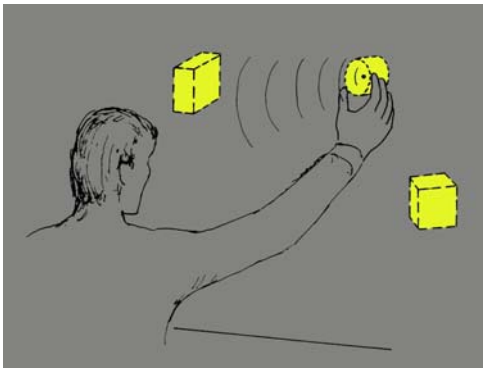


Listen into rooms which only exist on the construction board!

Binaural Room-Simulation System with Head-Tracker



Interactive Systems ➡ Virtual Reality



Sketch of a Multimodal (Audio/Tactile) VR

Generic Application Areas of Auditory Virtual Reality (VR)

Auditory Displays

e.g.,
for aircraft, road vehicles, control rooms, monitoring of action, teleoperation

Virtual Rooms

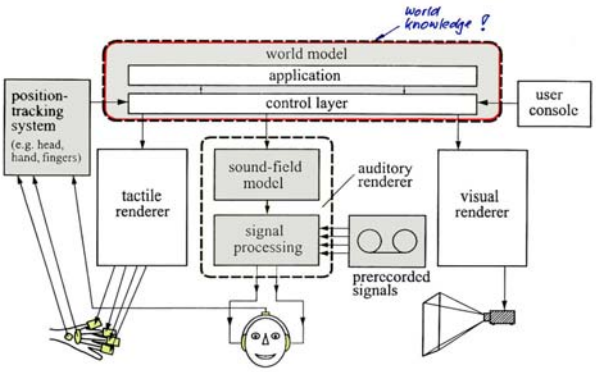
e.g.,
concert halls, recording studios, listening rooms, mixing rooms, rehearsal rooms

Auditory Representation in Multimodal Virtual Environments

e.g.,
motorcycle & truck simulators, systems for motoric training and rehabilitation, archiving of cultural heritage, interactive cinema, internet kiosk, telepresence

Tools for Research and Evaluation

e.g.,
audio-tactile experimental set-up to investigate the *Precedence Effect*



Block Diagram of a Multimodal Virtual-Reality Generator

(b) Computational Auditory Scene Analysis (CASA)

Generic Application Areas of Computational Auditory Scene Analysis (CASA)

Localization

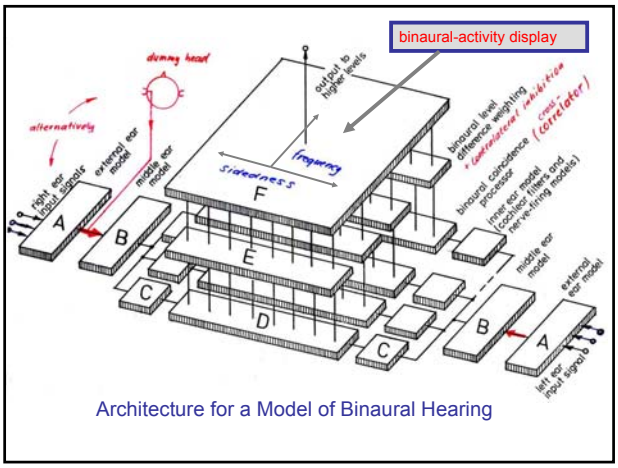
e.g.,
position finding of sound sources, spatial mapping of sound fields

Segregation and Decoloration

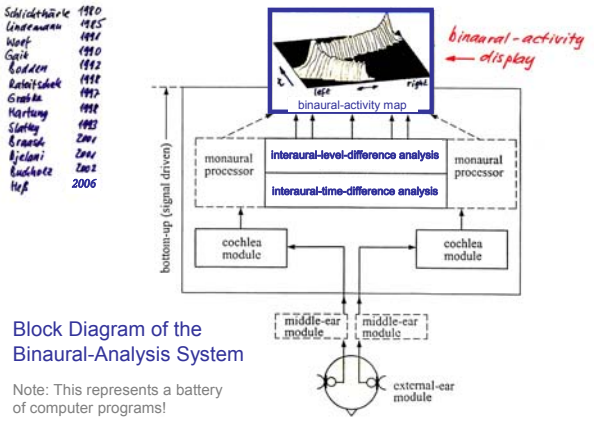
e.g.,
separation of concurrent sound signals, “cocktail-party processors”,
compensation of sound coloration as induced by reflections,
noise suppression, suppression of reverberance,
intelligent front-ends for hearing aids, intelligent microphones

Recognition and Tagging

e.g.,
robust speech recognition, sound-quality analysis,
speech-quality analysis, “content filters”

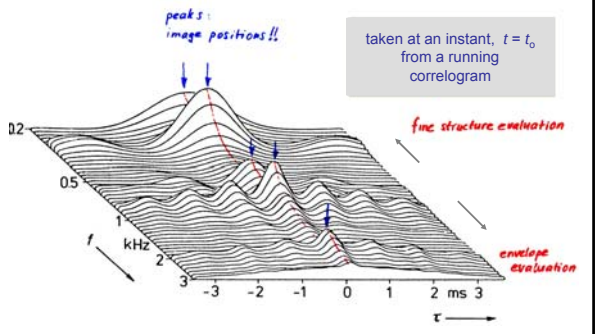


Architecture for a Model of Binaural Hearing



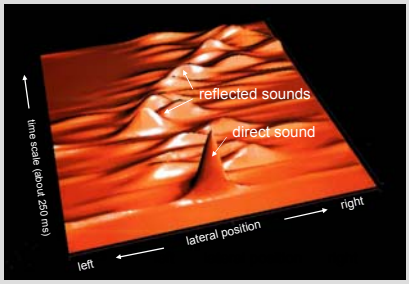
Block Diagram of the Binaural-Analysis System

Note: This represents a battery of computer programs!



Sample Output of the Binaural Model

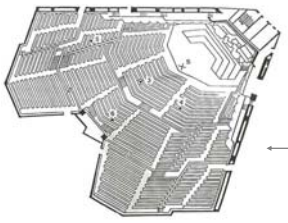
one frontal sound source, sending out a musical chord



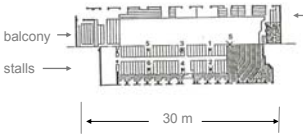
critical band about 700 Hz

Binaural-Activity Map of the Impulse Response of a Concert Hall

rendered by the model of binaural signal processing of *Lindemann & Gaik* 1986,1990 plotted by *Okabe* 1997

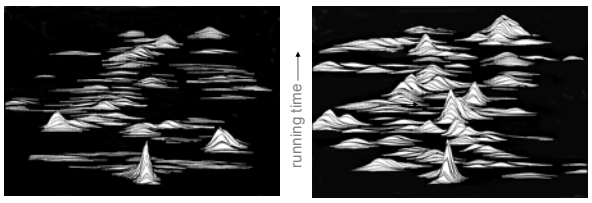


Philharmonie am Gasteig, D-Munich, a fan-shaped hall



Großer Musikvereinssaal, AU-Vienna, a show-box shaped hall

Plan of the Two Concert Halls Mentioned in the Next Slide



left < lateral deviation > right

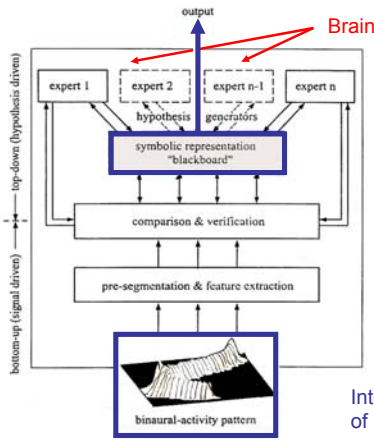
Gasteig, G-Munich

left < lateral deviation > right

Musikvereinsaal, Vienna

Binaural-Activity Maps of the Two Different Concert Halls

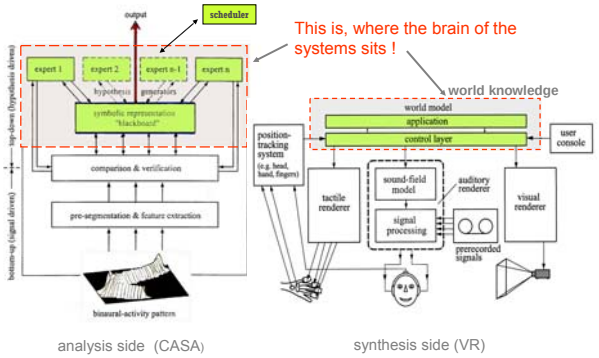
critical band about 700 Hz, 220-ms clip



Brain of the System
Subjectivity!

The „brain" of the system contains explicit knowledge: e.g., data bases, rule system, semantic networks, transition probabilities, domain models, the history of the situation

Intelligent Evaluation of of Binaural Activity



Processing of Content and Meaning in Communication Acoustics

What's currently happening in Communication Acoustics?

Modern communication-acoustical systems – now often realized as embedded components in more complex communication systems – contain an ever growing amount of built-in explicit knowledge.

Milestone #3

Communication Acoustics Gets Cognitive!

These developments call for knowledge and data from the cognitive sciences and for engineering expertise and skills necessary for importing this knowledge – and for representing and processing symbols, content and meaning in these systems.

(c) Sound Quality in the Context of Room Acoustics & Audio

Sound Character *descriptive*

Totality of measured values of features that are associated with the sound sample under examination

The measured values may relate to
different aspects of the sound, such as
an acoustic profile
an auditory profile

Further characteristic features may be included
if available, for example
an emotional profile
a cognitive profile

usually assessed by experts

Sound Quality *includes judgement*

sound character { is the result of an assessment of all features and feature values of a sound sample under examination which are recognized and nameable } judge-ment

reference character { in the context of judging upon their **suitability** to meet all recognized and nameable features and feature values of indivual expectations and/or social demands and/or pragmatic necessaries.

A Modern Definition of Sound Quality

adapted from *Jekosch* 2000

Product-Sound Quality
is a descriptor of the suitability*) of the sound attached to a product

includes judgement

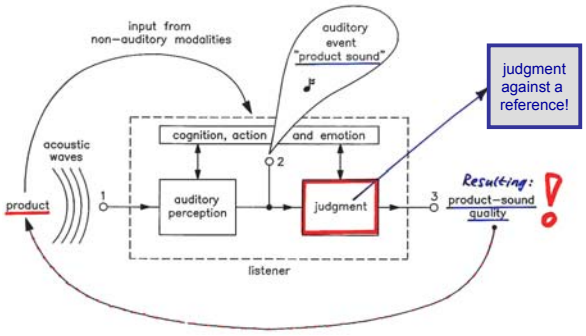
It results from judgements upon
the totality of auditory characteristics
of the said sound

- the judgements being performed with reference to
the set of those desired features of the product
which are apparent to the users
in their actual cognitive, actional and emotional situation.

judged by the user in the application context

*) in German: Eignung

after *Blauert & Jekosch* 1996



The Product-Sound-Quality Circle, or:
How Product-Sound Quality is Formed

Blauert & Jekosch 1996

Blauert & Jekosch 2003

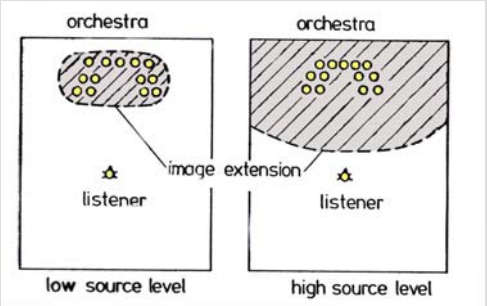
Character of a Sound
specified by feature profiles
(usually ascertained by experts)

Comparison, Appraisal, **Quality Judgment** (normally produced by the users)

Reference Set
specified by feature profiles
(ascertained by experts ??)

This block comprises
task dependency and
subjectivity (individuality)

Aural Quality of Systems − Towards a Unified Theory



The Perceptive Phenomena of Aural „Spaciousness“

pioneer researchers, e.g.,
Kuhl, West, Marshall, Barron, Schroeder, Morimoto

$$k = \max_{\tau} \left(\frac{\frac{1}{2T}\int_{-T}^{+T} x(t)\,y(t+\tau)\,dt}{x_{rms} \cdot y_{rms}} \right)$$

renamed by *Ando* to IACC

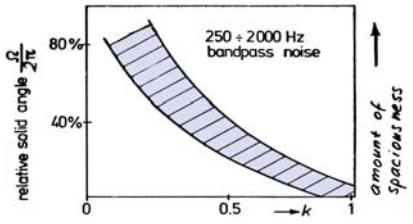
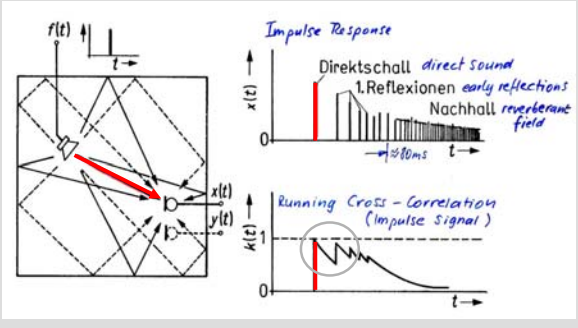
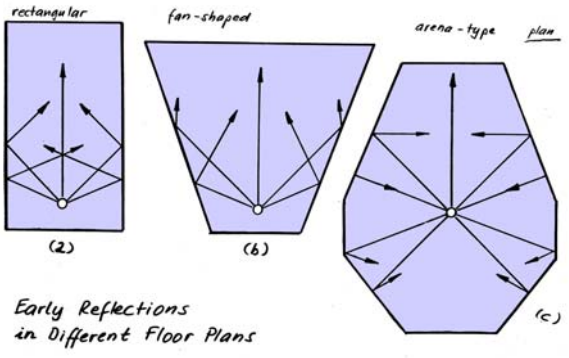


Image Extension as a Function of the Interaural Coherence, ***k***

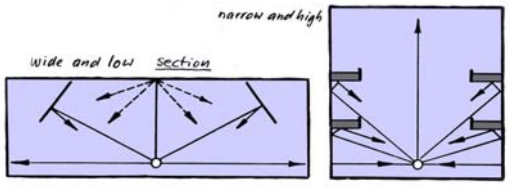
Damaske 1968



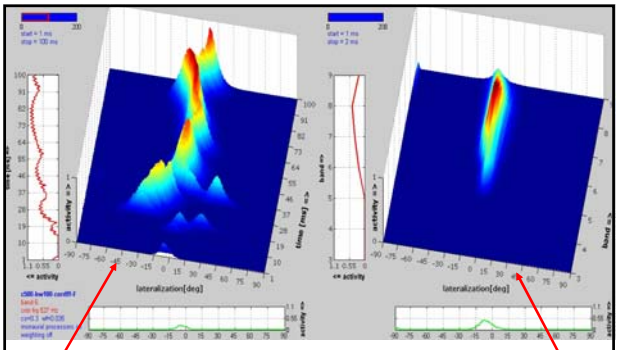
Impulse Response and
Running Interaural Cross Correlation
in a Room with Reflecting Walls



Auditory Spaciousness in Concert Halls
The Role of Lateral Reflections



Auditory Spaciousness in Concert Halls:
The Role of Lateral Reflections



critical band at 500 Hz — 2 noises from Φ = 30 & 330° 90% correlated — snapshots across bands

Binaural Model – Fast PC Version

after *Hess* 2004

video

Abstraction Level of the Character of the Reference for Different Concepts of "Sound Quality"

Higher

Abstraction

Lower

Product-Sound Quality	**"sound of quality"** ideas, concepts, functionalities, plausibility, sound as a sign carrier
Auditory-Scene Quality	**"quality of presentation"** aural gestalt, authenticity, enhancement, aural perspective, immersion
Transmission Quality	**"quality of realization"** acoustic attributes & properties, "transparency", physical form
Sound Quality (as such)	**"quality of sound"** auditory attributes & properties, perceptual form

Some Keywords to Consider

Typicalness

Functional Adequacy

Listening Tradition

Aesthetic Form

Classical Concert Halls

Hardware, persistent (bricks, stones and wood)

Since > 100 years

Rectangular "shoe-box" form (Basilica)

Sound sources: acoustic musical instruments
human voice

Program: baroque,
classical and romantic music

Modern Concert Halls

Hardware, persistent (concrete)

Since > 100 years

Fan-shaped and arena-shaped plans

Sound sources: acoustic musical instruments
human voice

Program: as with classical halls,
plus modern music

Analogous Electro-Acoustic Installations

Hardware, slowly variable

Since > 25 years

Acoustic modification of classical and modern halls

Sound sources: amplified musical instruments
amplified human voice

Program: amplified, electro-acoustically modified music, and
music generated by
analogous electronic devices

Digital Electro-Acoustic Installations

Software, instantly variable

Since only a few years (≈ 8 years)

Acoustic modification of classical and modern halls, auditory virtual environments

Sound sources: amplified musical instruments
amplified human voice
sampled and electronically generated sounds

Program: amplified, electro-acoustically modified music, all kinds of electronic music

As to the Role of the Consultant in Modern Room Acoustics

Tasks of an Up-to-date Acoustical Consultant

- Providing references
  - documentation (parametric representation, VR)
  - setting and specification of tradition
- Prototyping
  - understand the invariant components
  - parametric representation whenever possible (simulation, VR)
- Education
  - recognizing aural features
  - deciphering the "code", learning the "language"
- Tools
  - translation of aural features into built form (simulation, VR)
- Creative Design
  - from architectural acoustics to ⇨ **Aural Architecture**

take-home message

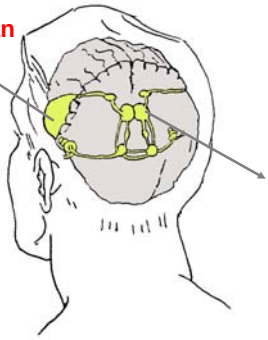
When dealing with the „quality of the acoustics"

Read the world from the listeners' point of view !

This means for us: We have to include perception, cognition and judgement into your consideration

What does the sound **mean** to me ?

Function



Form

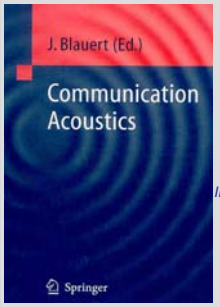
Where and how **is** the sound ?

The Human Auditory System:
Audition and Cognition Come in Couples

Thank you!

jens.blauert@rub.de
http://www.ruhr-uni-bochum.de/ika

For further reading, we propose the following collection of 14 review papers, including 4 on quality issues



Communication Acoustics
***Jens Blauert*, ed. (2005)**

Authors: *Jens Blauert, Jonas Braasch, Hugo Fastl, Volkmar Hamacher, Dorte Hammershøi, Ulrich Heute, Inga Holube, Herbert Hudde, Ute Jekosch, Georg Klump, Armin Kohlrausch, Arild Lacroix, Henrik Møller, Sebastian Möller, John N. Mourjopoulos, Pedro Novo, Steven van der Par.*

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