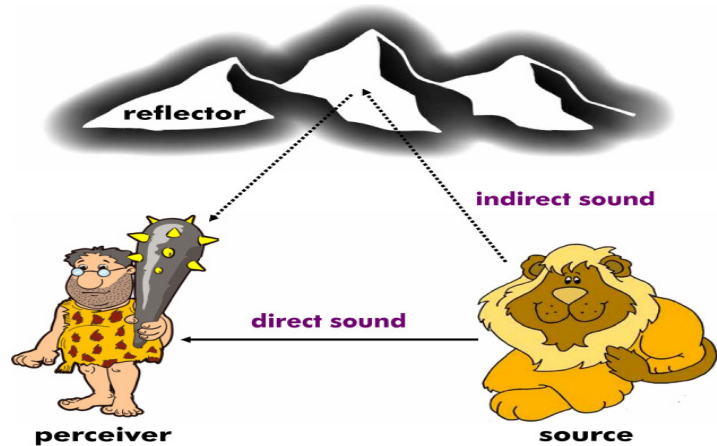


# Towards an ecological evolutionary psychoacoustics of music

Richard Parncutt  
Department of Musicology  
University of Graz, Austria



## Importance of psychoacoustics for music theory and music psychology

Psychoacoustical principles *limit* and *shape* experience.  
 • *limit*: What is audible? What is perceptually relevant?  
 • *shape*: Principles of grouping, association → meaning

### Neglect of psychoacoustics

Many consider psychoacoustics irrelevant. Why?  
 • Are music theorists not appropriately trained?  
 • Has the musical relevance not been made clear enough?

### A possible solution

Situate psychoacoustics in broader contexts  
 • ecology: role of environment  
 • evolution: role of survival and reproduction

## Evolutionary-ecological approach

### Evolutionary aspect

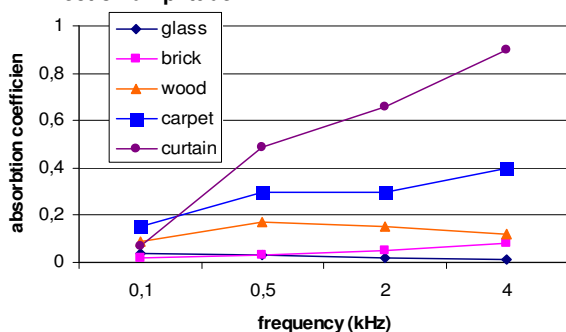
Hearing enables *recognition* and *evaluation* of sources.  
 • danger: fight, flight, freeze → survival  
 • social interaction → reproduction

### Ecological aspect

Psychoacoustics depends on physics of environment.  
 Environment is full of reflectors (incl. the ground).  
 Signal at ear is always a superposition of direct and indirect.  
 Indirect sound is reflected and delayed.

## Effect of reflections

### Effect on amplitude



Acoustic absorption of reflectors (Terhardt 1998 p. 140)

### Effect on phase

At medium-high freq., path difference = many wavelengths!  
 e.g. if path diff. = 5 m, delay = 15 ms (at 1 kHz: 15 periods)  
 → phase difference between direct, indirect is pseudo-random  
 → phase differences among partials are randomized  
 → waveform changes considerably

Both the waveform and phase relationships among partials are unreliable sources of information about the sound source.

## Why does ear separate frequencies?

At mid-high freq., only *frequencies* and *rhythms* are reliable sources of information about sound sources. This fact affected the evolution of hearing in all life (animals, insects, fish...)  
 (Terhardt, *Akustische Kommunikation*, Springer-Verlag, 1998)

Is human ear really more sensitive to frequency than amplitude?

- *frequency*: 10 JNDs/semitone x 100 semitones = 1000 JNDs
- *amplitude*: 1 JND/dB x 100 dB = 100 JNDs

## Monaural phase sensitivity

Evolutionary-ecological theory:

- monaural phase relationships are informative only at *low frequencies* and *during sound onset* (before second wavefront) (Haas effect is binaural and involves localization not identification)

Physiological (physical) limitations:

- phase relationships are maintained throughout auditory system
- phase effects are stronger within auditory filters
- phase relationships between filters are distorted by traveling wave delays in the cochlea (Patterson)

## More ecological-evolutionary theory

Q: Why does a harmonic complex tone have one pitch, although several partials are audible? Why is it at the fundamental?

A: The fundamental is a reliable indicator of source size/tension.

Q: Why is critical bandwidth approx. 2-3 semitones in the mid-high range and bigger at lower frequencies?

A: This compromise separates enough partials to enable phoneme discrimination in noisy backgrounds while still enabling fine temporal discrimination (uncertainty principle).

## Implications

### Auditory scene, music notation

Frequency and time are the main axes

### Timbre

- strong dependence on spectral and temporal envelope
- negl. dependence on waveform and phase relationships

### Musical structure = melody, rhythm, harmony. Why?

Three possible explanations

1. prenatal environment: sound patterns of voice, heart, feet.  
 → ultimate source of musical meaning and strong emotion?
2. adult environment: invariant patterns (harmonic series, pulse)  
 → octaves in frequency but not amplitude
3. auditory JNDs allow for more musical complexity in freq, time

**Acknowledgment.** Annemarie Seither-Preisler gave valuable comments.