Aalto University
School of Electrical
Engineering

Communication acoustics
Ch 8: The Approach and Methodology of Psychoacoustics

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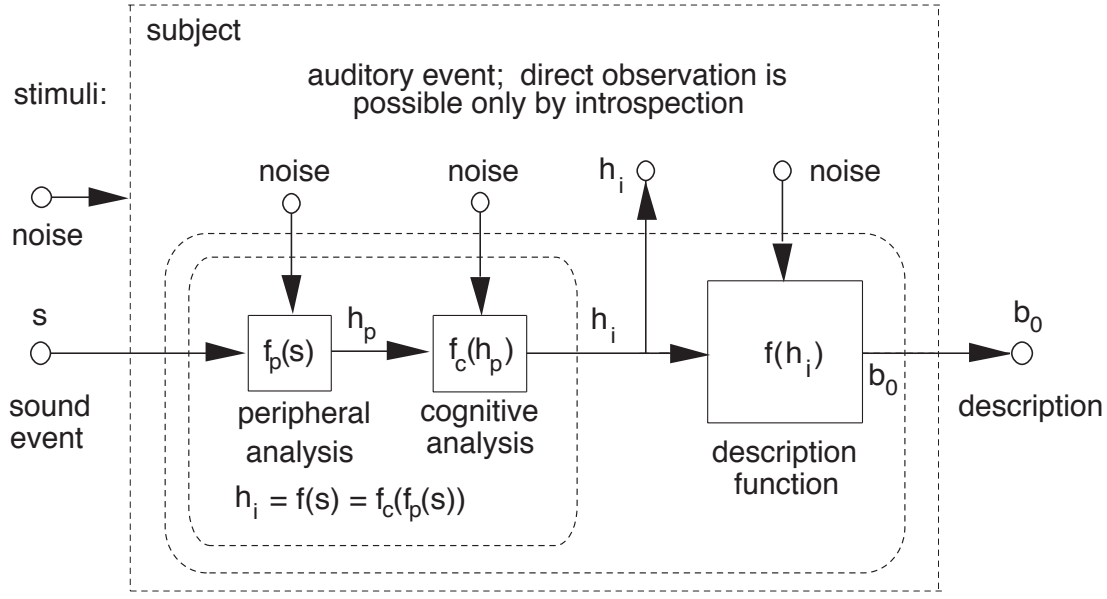
This chapter

- Fundamentals of psychoacoustics
- Psychophysical functions
- Practical running of listening tests
- What to measure?
- How to measure?
- Basic methods
- Advanced methods (Descriptive sensory analysis)

Psychophysics / psychoacoustics

- Systemic view to human as listener
- Sound events: Physical events
- Auditory events: subject's internal events that often correspond to sound events
- Properties of auditory events can be measured only through the description by the subject



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- Ask a question, and collect the answer:
  - Do you hear a sound?
  - Which vowel is this sound?
  - You hear two sounds, A and B. Which one is louder?
  - Adjust sound A to have the same loudness with sound B.
  - Describe which dimension do these two sounds differ, and how much?

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- Repeat this for many times
- Analyze data

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- Practical design
  - Selecting the method to present sounds
  - Select the question
  - Select which test method is used
  - Decide how many times tests are repeated
  - Select subjects: e.g., experts/non-experts, age groups, gender, hearing deficits

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  - Temporal length of samples

Listening set-ups

- Loudspeakers
  - Anechoic chamber
  - Standardized listening rooms
  - Concert halls, other special acoustic spaces
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- Headphones
  - Types: open, closed, in-ear
  - Delivering desired pressure spectrum is challenging at high frequencies
  - Careful equalization needs measurements with microphone inserted into ear canal
  - Auditory events are localized often inside the head

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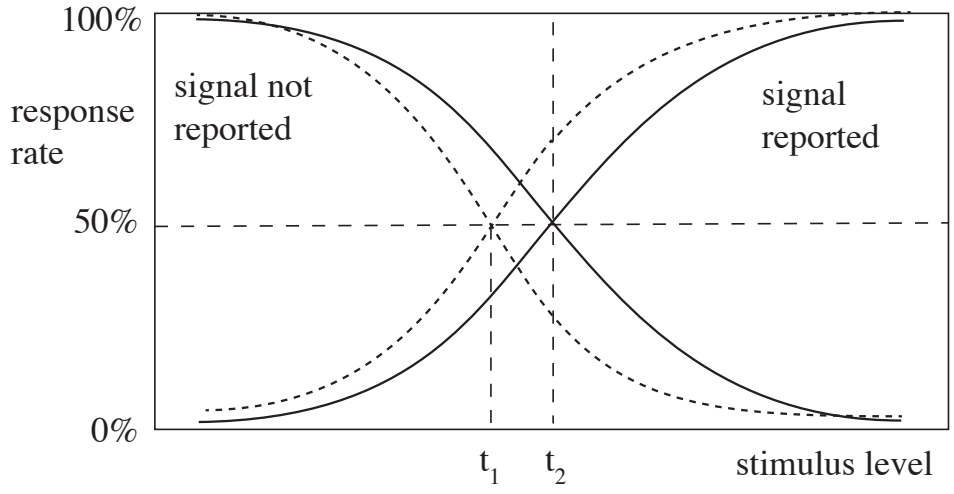
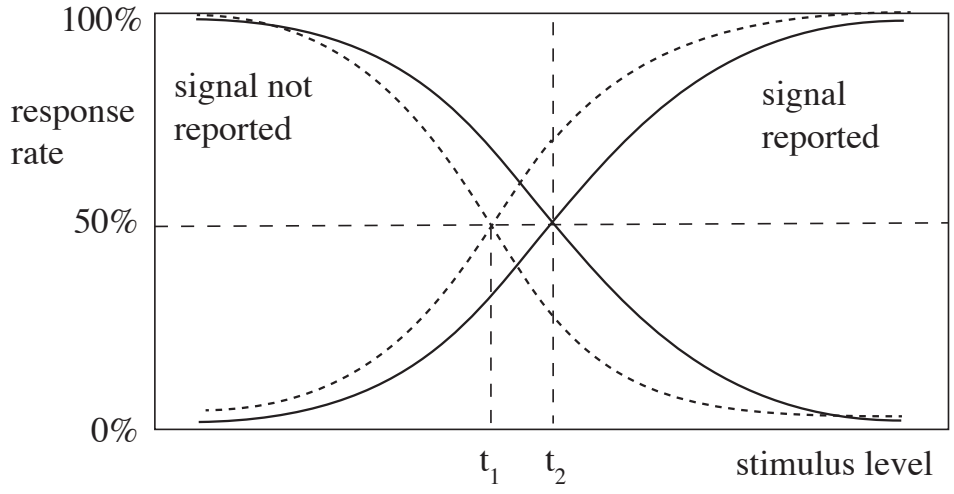
  - Just noticable difference (JND)
  - E.g., what is the smallest frequency difference of two sinusoids that you hear a difference?

Thresholds



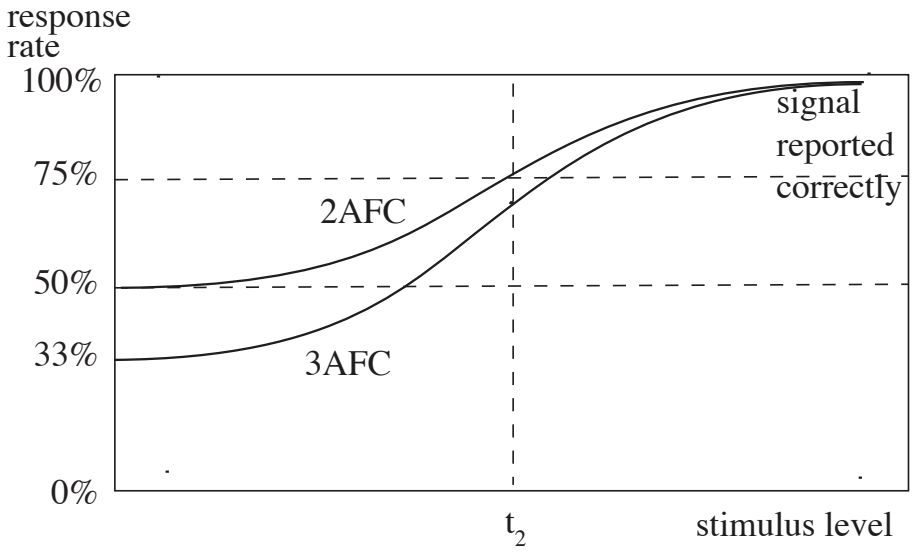
- Press button when you hear the sound.

Thresholds



- Press button when you hear the sound.
- Some people are more optimistic or pessimistic
- How to avoid bias due to different types of subjects?

Thresholds with forced-choice tests



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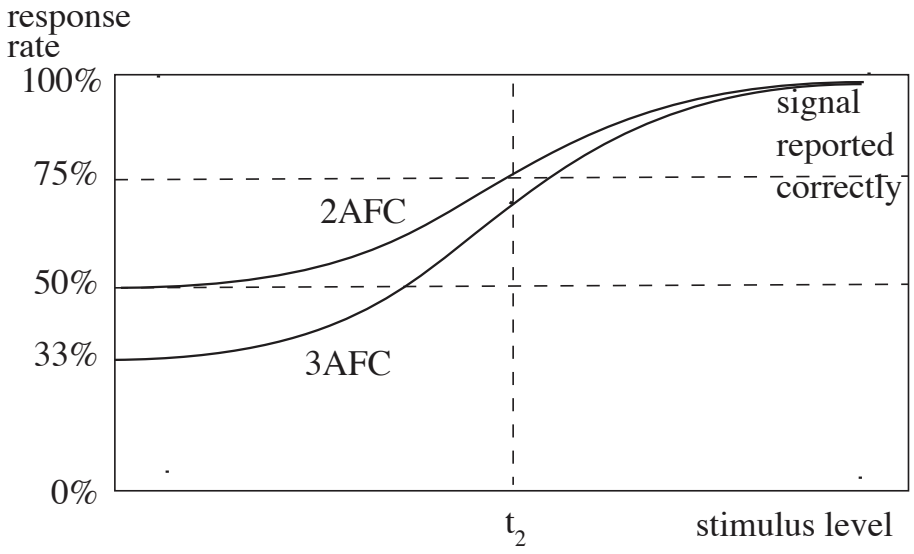
- Is the sound present during A or B?

Thresholds with forced-choice tests



- A and B buttons will be lit for 2s consecutively.
- Is the sound present during A or B?
- Two-alternative force choice (2AFC)
- Level of optimism or pessimism does not affect the result

Scales

- What higher is the sound pressure level of sound event (e.g., loudspeaker), that higher loudness is perceived to corresponding auditory event

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- What higher is the sound pressure level of sound event (e.g., loudspeaker), that higher loudness is perceived to corresponding auditory event
- Can we measure a scale for loudness, i.e., give numeric value to perceived loudness?
- We are not good in absolute judgment of auditory quantities
- Auditory memory is short, and hearing system adapts constantly to the environment
- Objective and repeatable results can be obtained by comparing two auditory events

Scales

- Nominal scale, events are categorized to classes without any order
- Ordinal scale, the order of the events is defined (this is louder than that)
- Interval scale, the difference between positions in a scale is defined
- Ratio scale, position of zero in scale is also meaningful

Numbering in scales

Often in listening tests the listener gives a numeric answer

- 1.0 — 5.0 (with 0.1 intervals)
- 1 – 100
- Verbal descriptor may be attached (bad, poor, good, excellent)
- Often there is no numbering, but just a slider, and descriptors in each end (soft – loud), (low – high)

Tasks for subjects

- Detection (is sound present)
- Discrimination (is this different from that)
- Forced choice (select one of these)
- Direct scaling (grade the quality from 4 to 10)
- Adjustment (adjust this acoustical parameter until auditory event has this quality)
- Chronometric task (do this as fast as you can)
- Verbal descriptions
- Other tasks

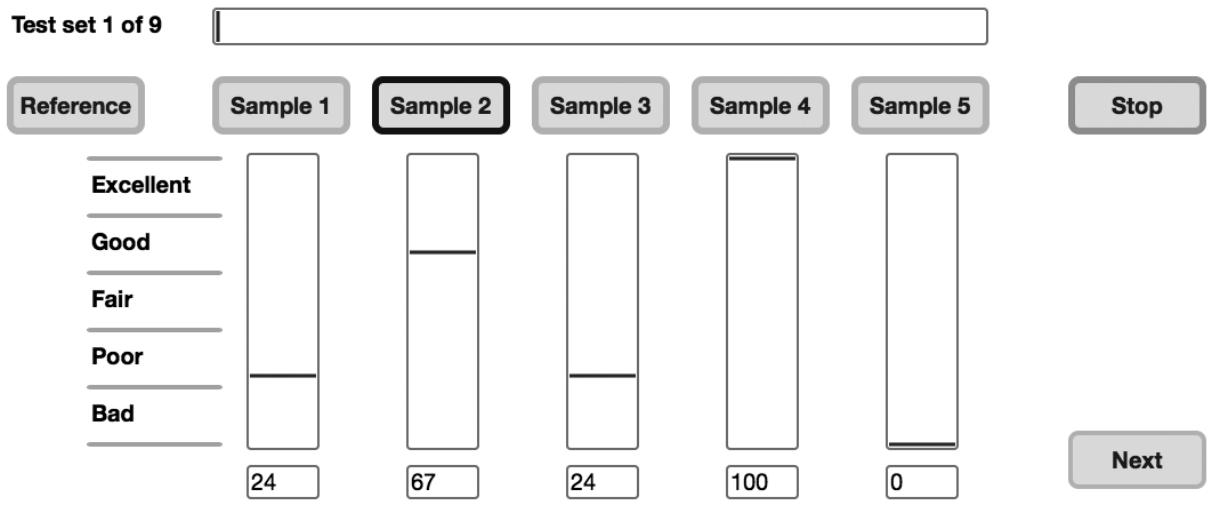
Test methods

How to present tasks to the subject in succession to measure a property of auditory event. The methods differ in how they vary the level of acoustic parameter, and how the responses of the subject are taken into account.

- Method of constant stimuli
- Method of adjustment
- Method of tracking
- Direct scaling
- Adaptive staircase

Direct scaling

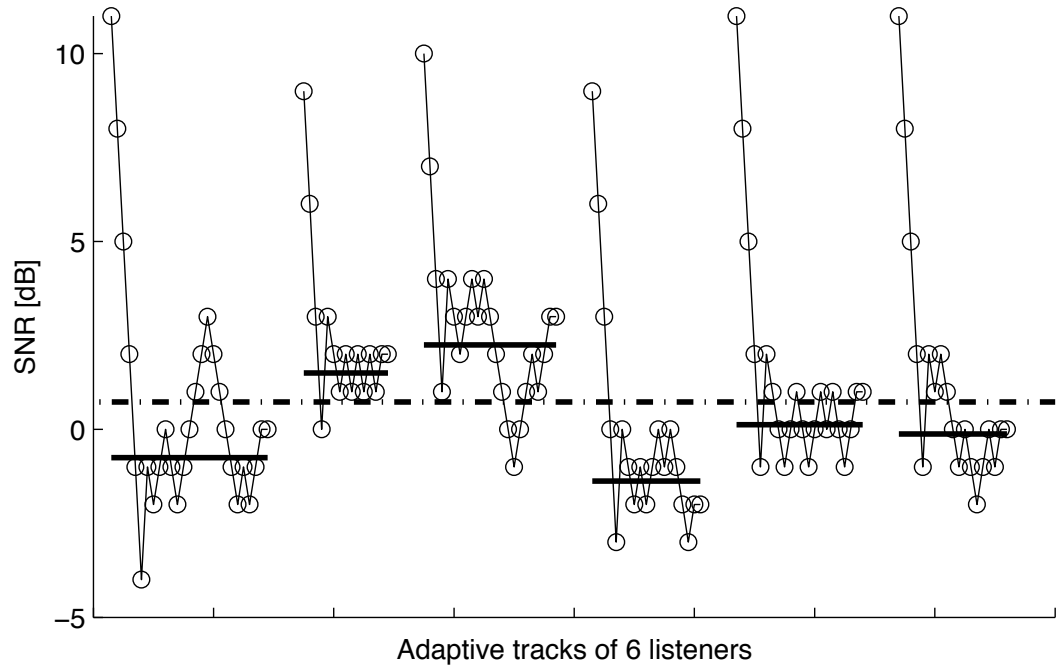
- Subject scale single or multiple auditory events, with or without reference
- Multiple-stimulus test



▸ Link to existing test

Adaptive staircase

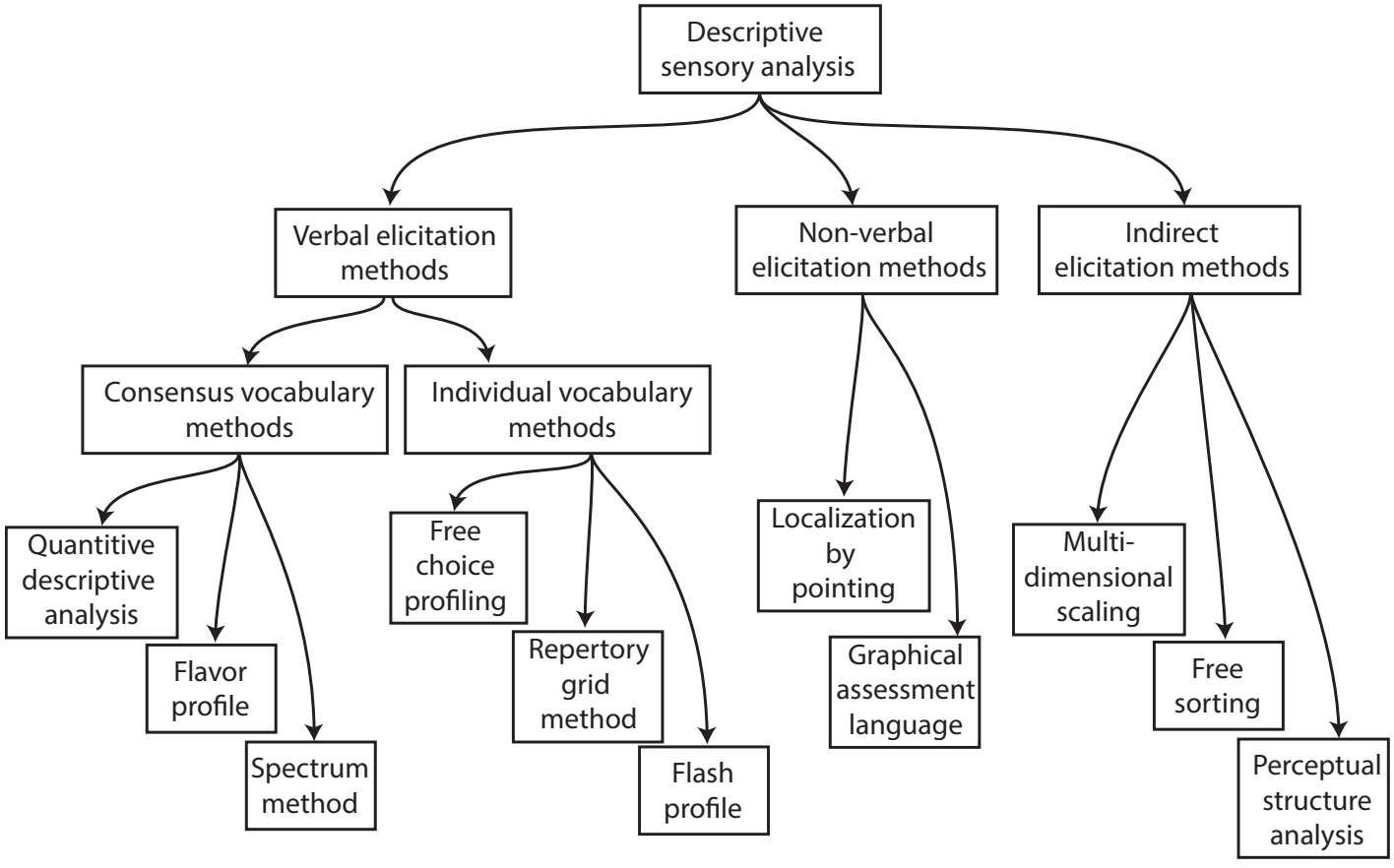
- Subject performs 2AFC or (N-AFC) test
- The level of acoustical parameter is varied
- With correct answer, the task is made harder, and vice versa
- The level should converge to the threshold that is searched for



Descriptive sensory analysis

- Auditory events studied may differ from each other in multiple dimensions, e.g., different cars have different indoor sounds
- Task is to define the dimensions, and then scale each auditory event in those dimensions
- May need rigorous experimentation to find the dimensions (sensory palette)
- Food industry (wine, coffee, yoghurts, etc.), Cosmetics (fragrances, lotions)
- Also utilized in sound quality (audio reproduction systems, hearing aids, concert halls)

Descriptive sensory analysis



(elicitation: the process of getting information from someone)

Examples of descriptive sensory analysis

- *Repertory grid technique*. Three samples are presented, where each assessor states the characteristic for which two of the samples are similar to each other and different from the third. After a number of trials, an individual set of descriptors of the dimensions is obtained and can then be applied to evaluate all the stimuli. Different types of data analysis, such as principal component analysis, can be exploited to study individual and multiple aspects of the experiments.
- *Multidimensional scaling*. The listener rates the perceived dissimilarity pairwise between all combinations of the samples, thus forming distance matrices between the samples. The matrices are scaled to a lower-dimensional space for easier interpretation. The perceptual attributes are assumed to be present in the resulting space. However, the distance matrices alone do not offer a way to interpret the perceptual dimensions associated with the spatial map, because no labelling of the sensation is asked of the subjects.

Attribute palette measured for hearing aids

ATTRIBUTE	ANCHORS	DEFINITION
Fullness	Thin – Full	Is the sound thin and tenuous, or mellow and full? A thin sound can be perceived as a lack of bass.
Sharpness	Little – Much	Sharpness describes how dominate the bright sounds are. If the sound is very sharp, 's'- sounds may be perceived as screeching to the ears. Sharpness can also be perceived as shrill sound. Much sharpness can be perceived as too much treble, and a lack of bass.
Naturalness	Artificial - Natural	Naturalness is characterized by easy recognition of the sound source, and gives a clear image of the source. The opposite is something which sounds artificial, or processed, or doesn't give a feeling of recognition.
Tube Sound	Little – Much	Sounds like holding a metal tube or seashell next to the ear. The sound becomes hollow and remote, or as if it contains more than one voice. Can also sound like an old-fashioned portable gramophone (with a horn speaker). Can also resemble sound coming through tubes of different diameters. May also sound whooshy.
Distortion	Clean - Distorted	Can be perceived as something loose that is rattling in the headphones. Can also be perceived as a vibrating sound, or as if a sound has been added.
Loudness	Soft – Loud	Refers to the general loudness level of the hearing aid.

Legarth et al. (2012, August). Establishing and qualifying a hearing impaired expert listener panel. Poster presented at the 2012 International Hearing Aid Research Conference (IHCON), Lake Tahoe, CA.

References

These slides follow corresponding chapter in: Pulkki, V. and Karjalainen, M. Communication Acoustics: An Introduction to Speech, Audio and Psychoacoustics. John Wiley & Sons, 2015, *where also a more complete list of references can be found.*