PSY-2007S

# Auditory Experimentation

week 2 – Introduction to Psychoacoustics

## Introduction to Psychoacoustics

threshold
absolute threshold
discrimination threshold
method of constant stimuli
method of limits
method of adaptation
staircase method
up-down transformed method
dB (SPL, SL, HL)
hearing curves

## How do we study (sound) perception

Naturalistic approach: observe your own perceptual experiences. Often the basis of a more formal line of study. Problems of systematic study, subjectivity, verbal reporting.

Experimental approach (control over stimulation):
Psychophysics – study of the relation between stimulus and sensation
Biopsychology – study of the relation between stimulus and brain function (EEG, MEG, fMRI, TMS, lesions, etc.)

Theoretical approach: implementation of computational models that replicate the relation between stimuli and perception and generate testable hypotheses.

## Psychophysics

What is the smallest amount of a certain stimulus quality that can be perceived?

What is the smallest difference between two stimuli that can be perceived?

When do two stimuli appear the same?

What is the relationship between the value of a stimulus attribute and the perception of that value?

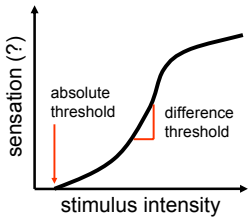
## Psychophysics

Started as a new science by Fechner in 1860 with his book *Elements of Psychophysics*:

"… an exact theory of the relation of body and soul, of material and mental, of the physical and the psychological worlds"

In other words: find a mathematical relation between stimulus and sensation!

## Psychophysics




In other words: find a mathematical relation between stimulus and sensation!

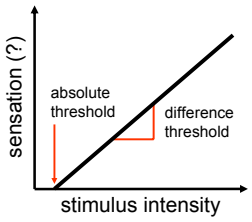
## Psychophysics

Important concept: Threshold

The absolute or detection threshold is the smallest intensity of a stimulus that can just be noticed.

The discrimination threshold is the smallest change in the intensity of a stimulus that can just be noticed (JND).

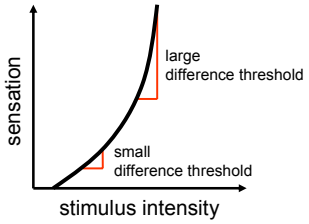
## Psychophysics




If the relationship were a straight line, the discrimination threshold would be constant (only need to measure once).

## Psychophysics

But the discrimination threshold is not a constant!
Weber discovered in 1860 that it is a constant fraction of the stimulus intensity :




Weber's law: $\Delta I / I = k$

## Psychophysics

Fechner invented 3 methods to measure thresholds:

The method of constant stimuli
The method of limits
The method of adaptation

In all 3 cases:
To measure absolute thresholds a weak stimulus is presented and test subjects respond with "*Yes I hear it*" or "*No, I don't hear it*".

To measure discrimination thresholds a standard stimulus and a comparison stimulus is presented and the subject responds with for example "*louder*" or "*softer*" (or sometimes "*same*" or "*different*").

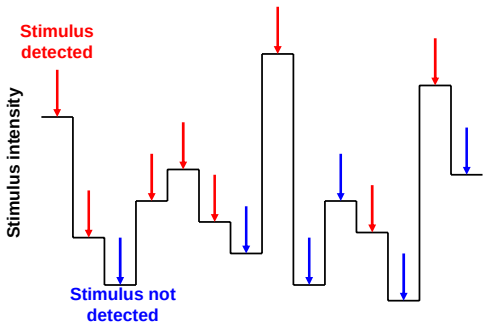
## Method of constant stimuli

Stimuli with a fixed range (for example from silence to 60dB in 2 dB steps) of intensity levels are presented several times in random order.

The threshold is the point where people hear the stimulus 50% of the time. (Responses are often plotted against stimulus intensity to give a "psychometric function". We'll come to that in a bit.)

Very accurate, but takes a long time!
(In the example: 30 stimuli, repeated 10 times = 300 stimulus presentations)

## Method of constant stimuli

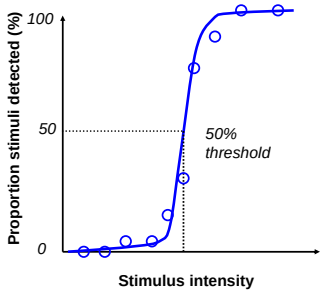


## Method of constant stimuli

For each level of stimulus intensity, calculate and plot proportion of stimuli detected/discriminated

Fit psychometric function to data

Threshold is stimulus intensity at the inflection point (in the middle of the curve).




## Method of limits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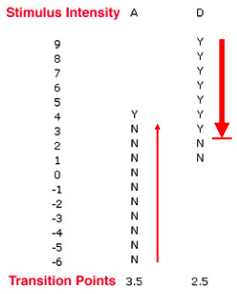


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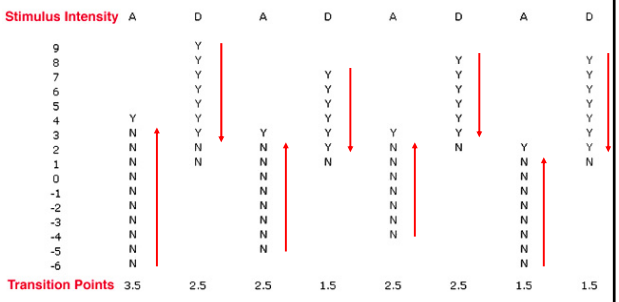
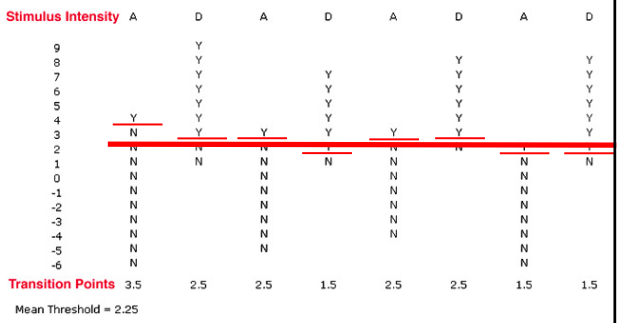
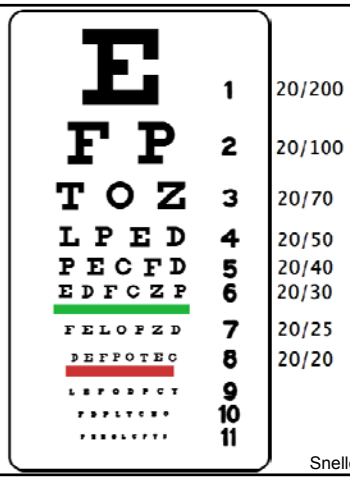


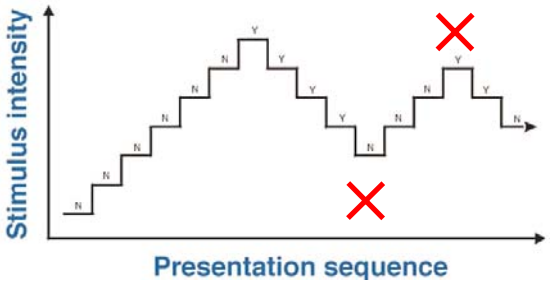
## Method of limits



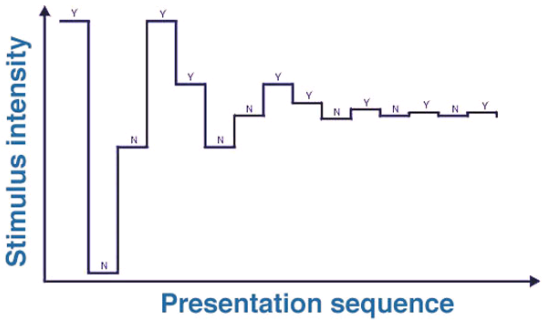

Snellen chart (1865)

## Staircase: spend more time close to the threshold by cutting off extra pieces



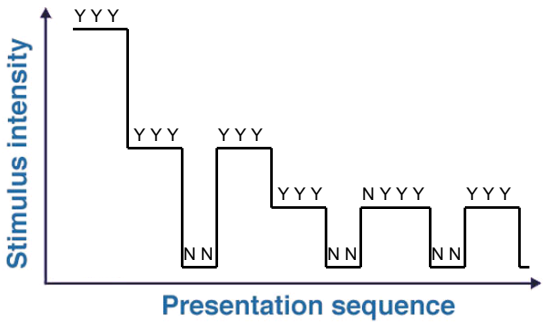

better yet. double staircase

## Spend more time close to the threshold by making smaller steps




good method, better when interleaved (but problems with interrupted runs)
To make single errors count less: Up-down transformed methods.

## Up-down transformed (2Up 3Down)




## Method of adaptation

With this method the test subject has control over the stimulus, not the experimenter!

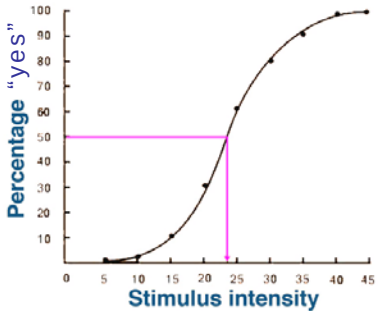
The subject adjusts the stimulus (using a button or a dial) to so that it is just heard or so that it is equal to another standard stimulus.

This is the fastest method! But it requires a stimulus continuum, and the ability to change the stimulus in real-time.

## Examples of sensory thresholds

| | |
|---|---|
| Vision | about 10 photons hitting a rod sensor<br>A candle flame at night from 50km. |
| Audition | the vibration of air particles 100 times smaller than the diameter of a hydrogen atom |
| Taste | 1 g of salt in 500 l water |
| Smell | one drop of perfume diffused through a 3-room apartment |
| Touch | the wing of a bee falling on your cheek from a height of 1cm |

## The Psychometric function




Yes/No procedure

## Loudness and sound intensity

The minimum pressure fluctuation to which the ear can respond is less than one billionth of atmospheric pressure.

Because of the wide range of pressure stimuli, it is convenient to measure sound pressures on a logarithmic scale, called the decibel (dB) scale. Although a decibel scale is actually a means for comparing two sounds, we can define a decibel scale of sound level by comparing sounds with a reference sound of a certain pressure, power, or intensity which is assigned a sound pressure level of 0 dB.

## The dB Scale

dB scale is a log ratio scale: Why? dynamic range!

Bel = $\log( I/I_{Ref})$
deciBel = $10 * \log( I/I_{Ref})$ Why? – 1dB ~ JND

Examples:
2:1 = log(2) = .3 * 10 = 3dB
10:1 = log(10) = 1 * 10 = 10dB
100:1 = log(100) = 2 * 10 = 20dB
(1000:1 ?)

## How to work with dBs

1. A sound is 23dB louder than another. What is the intensity ratio between them? (Physically, how much more intense is the second tone compared to the first?)

*23dB*
*20dB + 3dB*
*100 x 2 = 200 times as intense.* ($I/I_{Ref} = 10^{dB/10}$)

2. You are in a room with two speakers, each producing a 30dB noise. What is the noise level in the room?

*30dB and 30dB*
*1000 + 1000 = 2000, 10 * log(2000) = 33dB*
*or 2000 = 1000 x 2 = 30dB + 3dB = 33dB*

## How to work with dBs

2. You are in a room with two speakers, each producing a 30dB noise. What is the noise level in the room?

*30dB and 30dB*
*1000 + 1000 = 2000, 10 * log(2000) = 33dB*

3. You are in a room with a 30dB and a 3dB noise source. What is the noise level in the room?
*30dB + 3dB*
*1000 + 2 = 1002 = still 30dB! (30.009dB)*

## There is more than one reference sound level

**dB SPL**
Sound Pressure Level – absolute physical reference of $2 \times 10^{-5}$ N/m$^2$.

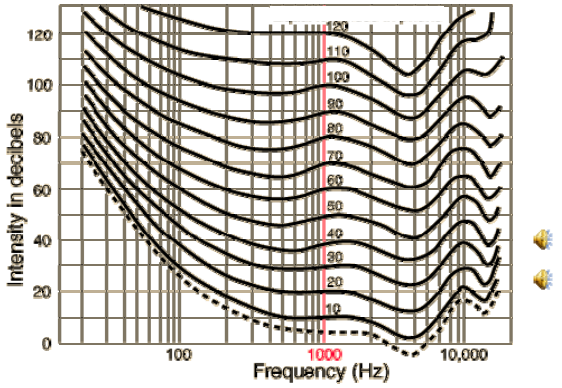
**dB HL**
Hearing Level – frequency dependent reference: the average hearing threshold at a frequency; takes into account the average hearing curve. How much louder is a tone than the threshold at the frequency?

**dB SL**
Sensation Level – depends on frequency and person: same as HL, but with individual hearing curve. How much louder is a tone than that person's threshold at that frequency?

| Source | Intensity | Level | Times > T |
|---|---|---|---|
| Threshold of Hearing | $1*10^{-12}$ W/m$^2$ | 0 dB | $10^0$ |
| Rustling Leaves | $1*10^{-11}$ W/m$^2$ | 10 dB | $10^1$ |
| Whisper | $1*10^{-10}$ W/m$^2$ | 20 dB | $10^2$ |
| Normal Conversation | $1*10^{-6}$ W/m$^2$ | 60 dB | $10^6$ |
| Busy Street Traffic | $1*10^{-5}$ W/m$^2$ | 70 dB | $10^7$ |
| Vacuum Cleaner | $1*10^{-4}$ W/m$^2$ | 80 dB | $10^8$ |
| Large Orchestra | $6.3*10^{-3}$ W/m$^2$ | 98 dB | $10^{9.8}$ |
| iPod at Maximum Level | $1*10^{-2}$ W/m$^2$ | 100 dB | $10^{10}$ |
| Front Row at Festival Concert | $1*10^{-1}$ W/m$^2$ | 110 dB | $10^{11}$ |
| Threshold of Pain | $1*10^{1}$ W/m$^2$ | 130 dB | $10^{13}$ |
| Military Jet Takeoff | $1*10^{2}$ W/m$^2$ | 140 dB | $10^{14}$ |
| Instant Perforation of Eardrum | $1*10^{4}$ W/m$^2$ | 160 dB | $10^{16}$ |

## Hearing curves and minimum audible field

The curves recommended by ISO:




## Vocabulary

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