Physiology Labs Protocols

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Labs aim: Explore biology in context through brain and hands

Hearing, Vestibular system, Stabilometry

Hearing is an important sense by means of which we can communicate with each other by analyzing relevant characteristics of sound waves, made up of pressure fluctuations of various frequencies and intensities evolving continuously in time, making up auditory signals that are through the outer and middle ear transmitted to the inner ear. There, they are transduced into a neuronal code that is conducted, interpreted, and integrated along the auditory pathway, arriving in the primary auditory cortex and associated cortical areas for complex processing.

The outer and middle ears play an important role in collecting and transforming air pressure fluctuations into pressure characteristics that can easily (thanks to the eardrum and ossicles providing a proper impedance interconnection – an impedance match) enter the inner ear - the cochlea, containing a liquid environment of endolymph and perilymph in which pressure fluctuations easily propagate, resonate the basilar membrane and stimulate corresponding hair cells of Corti organ by respecting the tonotopic principle. In hair cells, the transduction of sound mechanical energy into an auditory neuronal code happens made up of complex and precisely fired trains of APs well synchronized with timely sound characteristics, and analyzed further thoroughly in neurons constituting the auditory neuronal pathway (here various sound characteristics owing to auditory signals relevant to human's sound and speech perception and recognition are detected, extracted, integrated, and interpreted by analyzing frequency, intensity, binaural characteristics, and even more complex sound modulations).

Sound waves are reaching the inner ear mainly via propagating through the outer and then through the middle ear structures, whereas the amount of sound energy that is reaching the inner ear captured by the whole skull's surface area, and transformed into bone vibrations, is roughly two or three orders of magnitude smaller (expressed in sound pressure level units - by 20 to 30 dB smaller) since skull reflects approx. 99% of sound waves incident on it, leaving only 1% entering it due to a sudden change of impedance at the boundary separating the air and bone).

Thus, regarding the way a sound propagates into the organ of Corti, we either speak about the **air conduction** (via meatus and middle ear) or about the **bone condition** (skull and other tissue in the head). Whereas the bone conduction is rarely affected by some pathology, the air conduction is a subject of common diseases and affections impairing the conduction of sound through the meatus (plugs - buildup of earwax, etc.) or through the middle ear (fluid in middle ear, inflammation resulting in stiffening of ossicles articulations, otosclerosis, etc.), resulting in a **conductive hearing loss or conduction defect**. In case a reception and transduction of sound signals in the Corti organ is affected, including impairment of transmission of signals through vestibulocochlear nerve (n. VIII), we speak about a **sensorineural hearing loss or perception loss, or say a perception defect**.

Principles of the lab:

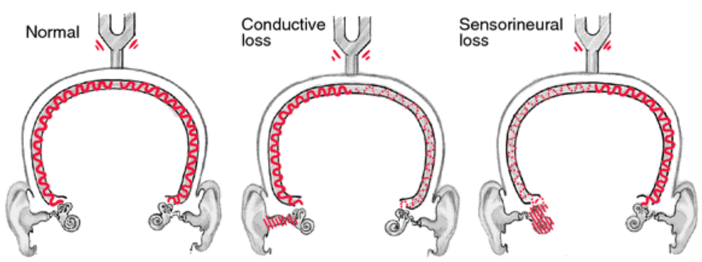
Tools available in labs, mainly **tunning forks**, take advantage of the fact that it is relatively easy to distinguish between **conductive hearing loss** and **sensorineural hearing loss**. Let's imagine that someone suffers from a conduction block (or impairment), say on the right side. Then, the Corti organ on that side becomes more sensitive to compensate for that hearing loss. However, if sound vibrations are distributed equally to both organs of Corti via bone conduction (which is expected to be not affected), distributing the sound energy symmetrically on both sides using a vibrating fork placed at the skull, the hearing is perceived louder at the side of impaired air conduction, assuming the tuning fork is placed at the middle line of the skull – that is the case if **Weber test** is performed. Mind, that this, paradoxical better hearing on the affected side during the Weber test examination does not mean this side would also hear better if sounds are received via air conduction – normally, the side affected by conduction defect hears worse obviously.

Mind, that in order for the Corti organ on the side of blocked air conduction to be more sensitive than its contralateral counterpart, the Corti organ on the healthy side must be desensitized, which would happen in rooms with noise levels around 20 -30 dB – in rooms which are commonly characterized as quiet rooms. The level of noise in such rooms causes the Corti organ to decrease its sensitivity on the healthy side more than on the affected side which receives less sound via affected air conduction becoming more sensitive than the opposite Corti organ of the unaffected side.

If the hearing problem is inflicted by a **sensorineural impairment**, the sensitivity of the ipsilateral Corti organ is expected to be decreased naturally. And, because the sound energy delivered to Corti organs via bone is distributed equally on both sides with a fork placed at the middle line of the skull – say during the Weber test, the affected side hears worse regardless of the way vibrations are delivered to the Corti organ – i.e., via air or bone conduction.

Tuning fork:

From Wikipedia: **A tuning fork** is an acoustic resonator in the form of a two-pronged fork with prongs (tines) formed from a U-shaped bar of elastic metal (usually steel). It resonates at a specific constant pitch when set vibrating by striking it against a surface or with an object, and emits a pure musical tone once the high overtones fade out. A tuning fork's pitch depends on the length and mass of the two prongs. They are traditional sources of standard pitch for tuning musical instruments. Tuning forks, usually C512, are used by medical practitioners to assess a patient's hearing. This is most commonly done with two exams called the **Weber test** and **Rinne test**, respectively.

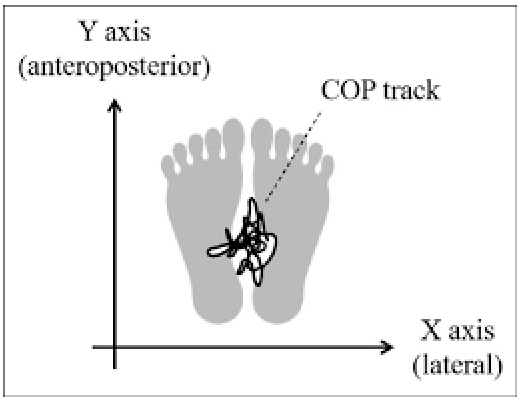



Audiometry

Pure-tone threshold audiometry is the measurement of an individual's hearing sensitivity for calibrated pure tones. In case the hearing threshold is estimated for pure tone frequencies, we speak about the **threshold audiometry** (requiring individuals to be placed in a soundproof or sound-isolated room, where they spend a short period prior to the measurement over which their organs of Corti adapt to the absence of any audible sounds, and become maximally sensitized). Then, the threshold for **air conduction** as well as for **bone conduction** can be tested. In case more complex hearing disorders should be resolved, individuals can be tested with **supra-threshold audiometry,** where responses to suprathreshold pure tones of various frequencies are evaluated to test the ***recruitment*** – a condition, or phenomenon resulting in a significant enhancement in perceived loudness in response to a very small increase in the intensity – most commonly observed in patients having sensorineural hearing loss).

Stabilometry and posturography

Stabilometry is an objective evaluation of body stability during quiet standing, i.e., stability of posture in the absence of any voluntary movements or external perturbations. The measurement focuses on characteristics of body sway during the upright standing, measured primarily by means of tinny platform movements on which patients stand. It is a non-invasive clinical examination used to evaluate the functioning of peripheral and central nervous system involved in the control of posture (sensory, motor, vestibular, visual, cerebellar, etc.).



Required knowledge:

- Sound pitch and intensity (typical frequencies of sounds)
- Decibel and other units
- Hearing threshold, control of sensitivity of the ear (middle ear, inner ear)
- Sound conduction (air vs bone)
- Conduction vs perception defect
- Tuning forks tests principles, audiometry principles

Overview of tasks:

1. speech test
2. tuning forks tests
3. audiometry
4. vestibular reflexes, nystagmus
5. stabilometry

Speech test

Aim: fast assessment of hearing at different frequencies (speech, whisper)
Procedure:

- Ask person being tested to stand in cca 5 m away and turned 90` from face-to-face position (in order to prevent reading lips) and repeat words yuo say
- Start saying words with hi-pitch and lo-pitch tones (cheese, see/root, boom) and wait for each to be repeated.
- Use both loud voice and whispering
- If person being tested cannot hear, ask to move closer
- Record the result as max. distance from which tested subject can repeat w/o hesitation.

Tuning fork tests

Aim: distinguish between conduction and perception=type hearing defect. Also to identify which ear is affected.
Principle: bone and air conduction are evaluated and compared

Air conduction – sound propagates thru middle ear (and thru outer ear). Typical for listening to external sounds.

Bone conduction – sound propagates thru bones of scull. Typical to listening to own voice. For external sounds, air conduction is (physiologically) substantially more sensitive

Tuning-forks tests overview

Test name	***procedure***	***What is tested***	***comment***
Weber	Tuning fork attached to bone in the mid-line	- Bone conduction. - If both ears hear equally	If one ear hears louder than cross-lateral one, this is called **Lateralization** and implies pathology
Rinne	Fork attached to mastoid process and once hearing ceases moved in front of the ear (same)	- Bone conduction and air conduction (of the same ear) - if hearing thru air conduction is longer than in bone cond.	*Normal finding:* sound is perceived longer via air conduction . Test is **negative** *Pathological finding:* sound is perceived longer via bone conduction
Schwabach	For attached to mastoid, once hearing ceases , doctor attaches fork to her/his own mastoid	Comparebone (and air) conduction between patient and doctor	*Normal:* patient and doctor can hear similar intensities

Tasks:

- perform all tuning fork tests. (everybody ,bilaterally, in quiet room)
- perform the tests again while simulating conduction defect
- Record all results
- try to interpret the results

AUDIOMETRY

Aim: estimate hearing threshold over the range of frequencies. Requires audiometer (specific device). May test both air conduction (loudspeaker) and bone conduction (vibrator). Audiometer in labs only allows for testing air conduction.
Use: diagnose various defects including: professional damage, presbyacusis)

Task: perform audiometry and record results into provided chart.
Procedure:

- check audiometer and earphones if properly connected
- work in silent room
- explain the procedure to the tested person
- instruct the person to indicate when he/she starts hearing testing sound
- ask the tested person to put the phones on
- make sure loudness is set to minimum
- turn on audiometer
- before every new tone being used, allow for brief listening at low intensity (to get acquainted with the frequency)
- for each frequency find hearing threshold of each ear. Note: while slowly increasing the intensity, use button to periodically interrupt the tone (ca 1x per second).
- Plot the results into graph
- Try to interpret the finding

Questions:

- Why more than one tuning fork test is needed for proper diagnosis?
- Why tuning fork tests do not require sound-proof room?
- Why audiometry usually requires sound-proof room?
- During audiometry, why does the tested tone need to be periodically interrupted?
- Why in the sound-proof room the results of Weber tuning fork test might be unconclusive?
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