HUMAN SENSORY PHYSIOLOGY

INTRODUCTION

The human body contains a variety of specialized sensory structures, which allow us to detect different stimuli in our environment. In particular, we have somatic senses (cutaneous and proprioceptive) and special senses (hearing, vision, balance and equilibrium, taste, and smell) to detect stimuli from the external environment, and visceral systems to detect internal stimuli.

To perceive the environment around us, we need detectors. Our detectors are sensory receptors. We have different types of sensory receptors, each of which is specific to a particular energy form or modality. The function of the receptors is to detect the energy form and convert it through a process called transduction into neural impulses. The neural impulses then send a message via a relay in the thalamus to the cerebral cortex, making us consciously aware of an external stimulus.

Each sensory system has its own receptors and neural pathways. For example, the perception of vision starts with light activating photoreceptors (rods and cones) in the retina of the eye. Light changes the electrical properties of the photoreceptors and eventually leads to action potentials in the ganglion cells of the retina, which leave the eye as the optic nerve. These sensory neurons then synapse in the lateral geniculate nucleus of the thalamus on neurons that go to the visual cortex in the occipital lobe, where perception of light occurs.

The aim of the following experiments is to demonstrate various properties of our somatic and special senses. Please answer all questions on pp. 5-10.

EXPERIMENT 1: CUTANEOUS AND PROPRIOCEPTIVE SENSATION

a. <u>Two-Point Discrimination</u>: One person per pair will be the subject of this experiment. The same subject must be used in part b. Using two blunt points, you will determine thresholds of two-point discrimination at various sites on the body surface. The two-point threshold is the smallest distance between two points at which they are still perceived as separate points. One can only discriminate between two points if receptive fields of two different afferent fibers are being activated.

The subject should keep his/her eyes closed during testing. First, determine the minimum pressure you can apply with the aesthesiometer such that the subject senses it. Next, touch the person at various body regions (lips, finger tip, palm of hand, forearm, upper arm, back, forehead, and back of neck) with either one point of the aesthesiometer or both points, using a pressure just above the minimum to produce a sensation. Ask the subject to report whether you are touching him/her with one or both points of the aesthesiometer. By varying the separation between the two points, determine the minimum separation at which the subject can discriminate the two points. Record all of the individual results (actual distance between points and whether the subject reported feeling one or two points) for each site on pp. 5-6, and then determine the two-point discrimination threshold. Use repeated measurements with identical or similar actual distances, to establish accurate, reproducible results. You must test only one point periodically (zero distance between points) as a control. Keep the subject honest!

b. <u>Tactile Localization</u>: Have the subject keep his/her eyes closed. Touch the subject's skin with a single point from a ball point pen so as to leave an indentation. Remove the pen. Then, have the subject try to touch this exact spot using another pen or pencil. Measure his/her error of location in mm. Repeat, using the same stimulation point. Test tactile localization on the lips, finger tip, palm of hand, forearm, and upper arm.

c. Weber's Law (Proprioceptive Sense): We can perceive two intensities of stimulation as being different if they differ sufficiently. Weber's Law states that the required difference in strength of stimuli is related to the initial intensity of stimulus. The ratio of the intensity difference that can be detected (dI) to the initial intensity (I) is generally constant:

$$dI/I = C$$

We will test Weber’s Law by having the subject distinguish between different weights in each hand. One person per pair will be the subject for this experiment. The same person must be used for both 100 and 200 gram reference weights. Place a dish containing weights in each of the subject's hands. One dish should contain the reference weight, 100 g, and the other should contain a weight less than or equal to the reference weight. Ask the subject which weight is heavier or if they are the same. Use several different test weights with the same reference weight, and make multiple measurements to determine the minimum difference in weight that can be identified. Randomly vary which hand has the reference weight. Repeat the test using a second reference weight, 200 g.

d. Temperature Receptors: A station will be set up with three 400 ml beakers half full of ice water (0-5^{o}C), water at room temperature (22-25^{o}C), and warm water (~40^{o}C). (i) Place the subject’s left hand in the ice water and the right hand in the warm water for 1 minute. (ii) Next, quickly place both hands in the water at room temperature, and wait for 1 minute. Answer questions about temperature sensations on p. 7.

EXPERIMENT 2: HEARING

Please complete this part of the experiment in a quiet area, except part d. Answer questions on pp. 8-9.

a. Auditory Acuity: One student per pair will be the subject of this experiment. Have the subject hold a hand over one ear and close his/her eyes. Hold a watch that ticks in line with the open ear. Gradually move the watch away from the ear until the subject just loses the ability to hear the ticking. Measure the distance between the ear and watch at this point. Next, starting with the watch further away, move the watch toward the ear until the subject just hears the ticking. Measure this distance and compare it to the distance when moving the watch away from the ear.

b. Localization of Sound: One student per pair will be the subject of this experiment. With the subject seated with eyes closed, bring a watch within hearing range from several different angles around his/her head. Ask the subject to point to the direction from which he/she hears the sound. Record whether the judgment is better in the median plane or at the side of the head. In the median plane, record whether the judgment is more accurate above the head or in front of it. Repeat the experiment when the subject has one hand over his/her left ear.

c. Auditory Adaptation: Each student will be the subject of this experiment. Place a stethoscope in the subject's ears. Place a vibrating tuning fork near the bell of the stethoscope so that the sound seems equally loud to both ears. Remove the tuning fork and wait a minute or two. Pinch the stethoscope tube to one ear to occlude the tube. Place the vibrating tuning fork in its former position near the bell. After 5-10 seconds, open the pinched tube. Compare the intensity of sound heard by the two ears.

d. Weber Test: The same subject must be used for the Weber test and the Rinne test (below). This test should be performed at a normal noise level (not absolute silence, but not in the lab). Place the base of a vibrating tuning fork against the subject's head near the bridge of his/her nose. Ask the subject if the sound is heard equally in both ears or if one side hears better.

If one ear has a defect in the middle ear (conduction deafness), then the sound will actually be heard better in that ear because in the normal ear, the sound will be partially masked by environmental noise to which the defective ear is less sensitive. In addition, in the normal ear, the sound is often softened by the tensor tympani and stapedius muscles, which prevents the full amplitude of vibration of the auditory ossicles. This attenuation reflex is less effective or absent in conduction deafness.

If one ear has a defect in the auditory nerve or cochlear apparatus (nerve deafness), then the sound will be heard better in the normal ear because neural activity is essential for hearing.

e. Rinne Test: Place the base of the vibrating fork against the subject's mastoid bone (a bony projection of the temporal bone in the skull, just posterior to the ear) and start timing. Ask the subject to tell you when the sound is no longer heard, noting the number of seconds. Immediately place the still vibrating tines 1-2 cm from the auditory canal and ask the subject to tell you when the sound is no longer heard, noting the number of seconds. Air-conducted sound should be heard twice as long as bone-conducted sound. Test both ears.

If the ear has conduction deafness, then bone conduction should be heard longer than or equal to air conduction. If the ear has nerve deafness, then air conduction should be heard longer than bone conduction, but not for twice as long.

EXPERIMENT 3: VISION

a. Mapping the Blind Spot: There is a region of the visual field for each eye where objects are not perceived. This is the blind spot, and it corresponds to the part of the visual field that falls on the retina where the optic disk is located. There are no rods or cones at this point on the retina.

One student per pair should be the subject. To map the blind spot, draw a dot on the blackboard at eye level. Have the subject stand 100 cm from the blackboard, facing the dot. The subject should close one eye and fixate the other eye on the dot. Move a white point (e.g. chalk) horizontally on the surface of the blackboard at the subject's eye level, beginning at the fixed dot and moving in the direction of the open eye (if the right eye is open, move the spot to the right). Have the subject inform you when the spot is no longer visible. Mark this spot on the blackboard. Continue moving the white spot horizontally, until the subject reports that it is visible again. Mark this spot on the blackboard. Measure the distance from the original point to the point where the spot was first lost (a), and the distance from the point where the spot was first lost to the point where it was first visible again (b). Use these distances to estimate the diameter of the optic disk (see pp. 9-10). You can also map the blind spot in two dimensions if you wish to see how large is the area it encompasses. Do this by moving the white point in vertical and diagonal paths near the horizontal limits of the blind spot, or by shading the area and erasing visible portions.

b. Visual Acuity: Each student should test his/her visual acuity. Visual acuity measures the ability of the eye to focus images on the retina. If you wear corrective lenses, you may want to make the measurements both with and without the lenses and compare.

Your visual acuity will be measured with a wall chart, of the type used at a doctor's office. Stand 20 feet from the chart. Cover one eye and read the letters on the chart. The visual acuity index is the collection of numbers on the left side of the chart next to the smallest letters you can read accurately. These numbers represent the normal distance at which that row of numbers can be read. For example, if letters below the 100 feet line cannot be distinguished, the subject's visual acuity is 20/100, which means that the person can see at 20 feet what most people can see at 100 feet. Repeat for the other eye.

c. Astigmatism: Each student should test herself/himself for astigmatism. Astigmatism is caused by distortion of light rays entering the eye due to small defects in the curvature of the cornea. This defect is tested using an astigmatism chart. Stand 8-10 feet away from the chart and cover one eye. If you wear corrective lenses, then you may want to do this with and without wearing the lenses. If astigmatism is present, then some of the lines will appear clearer than others, and the lines at right angles will appear fuzzy.

d. Dominant Eye: Each student should determine his/her dominant eye. One eye is usually relied on more heavily than the other eye, and is called the dominant eye. To determine which of your eyes is the dominant eye, look through a tube with both eyes at an object across the room. Then, close one eye at a time. The eye that sees more of the object through the tube when it is the only eye open is the dominant eye.

e. Negative After-Image: Each student should observe negative after-images. Stare at a penlight for 10-15 seconds. Quickly turn away and look at a white surface.

f. Depth Perception: Each student should serve as the subject. Extend your arms to the side with the palms facing forward. With one eye closed, try to touch the tips of the index fingers together about one foot in front of your face. Repeat with both eyes closed and both eyes opened.

g. Retina Anatomy: Use the ophthalmoscope to view the inside of the eye. Move the ophthalmoscope in from the side or from above, rather than directly in front of the eye, and look at the pupil. You may need to do this in a relatively dark area.

REFERENCES

Kandel, E.R., Schwartz, J.H., and Jessell, T.M., Principles of Neural Science, 3rd edition, Elsevier, 1991, pp. 326-529.

Sherwood, L., Human Physiology: From Cells to Systems, 2nd edition, West Publishing Company, 1993, pp. 150-196.

Vander, A.J., Sherman, J.H., and Luciano, D.S., Human Physiology: The Mechanisms of Body Function, 5th edition, McGraw-Hill Publishing Company, 1990, pp. 219-254.

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LAB REPORT: HUMAN SENSORY PHYSIOLOGY

EXPERIMENT 1: CUTANEOUS AND PROPRIOCEPTIVE SENSATION

a,b. Two-Point Discrimination and Localization

Complete the following tables for two-point discrimination and localization. Record the actual distance (d, mm) between points and whether the subject felt one or two points, then determine the threshold as the minimum separation at which two points could be detected reliably (at least twice). Report localization distances for both trials at each point.

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Lips	_______	_______	_______	_______	_______	_______
Lips	_______	_______	_______	_______	_______	_______
Lips	_______	_______	_______	_______	_______	_______
Lips	_______	_______	_______	_______	_______	_______

Two-Point Discrimination Threshold (mm): _______
Localization (mm): 1. ___________ 2. __________

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Finger tip	_______	_______	_______	_______	_______	_______
Finger tip	_______	_______	_______	_______	_______	_______
Finger tip	_______	_______	_______	_______	_______	_______
Finger tip	_______	_______	_______	_______	_______	_______

Two-Point Discrimination Threshold (mm): _______
Localization (mm): 1. ___________ 2. __________

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Palm of hand	_____	_______	_______	_______	_______	_______
Palm of hand	_____	_______	_______	_______	_______	_______
Palm of hand	_____	_______	_______	_______	_______	_______
Palm of hand	_____	_______	_______	_______	_______	_______

Two-Point Discrimination Threshold (mm): _______
Localization (mm): 1. ___________ 2. __________

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Forearm	_______	_______	_______	_______	_______	_______
Forearm	_______	_______	_______	_______	_______	_______
Forearm	_______	_______	_______	_______	_______	_______
Forearm	_______	_______	_______	_______	_______	_______

Two-Point Discrimination Threshold (mm): _______
Localization (mm): 1. ___________ 2. __________

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Upper arm	_______	________	________	________	________	________
Upper arm	_______	________	________	________	________	________
Upper arm	_______	________	________	________	________	________
Upper arm	_______	________	________	________	________	________

Two-Point Discrimination Threshold (mm): _______
Localization (mm): 1. ___________ 2. ___________

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Back	________	________	________	________	________	________
Back	________	________	________	________	________	________
Back	________	________	________	________	________	________
Back	________	________	________	________	________	________

Two-Point Discrimination Threshold (mm): _______

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Forehead	________	________	________	________	________	________
Forehead	________	________	________	________	________	________
Forehead	________	________	________	________	________	________
Forehead	________	________	________	________	________	________

Two-Point Discrimination Threshold (mm): _______

Area	Distance	One/Two	Distance	One/Two	Distance	One/Two
Back of neck	_____	________	________	________	________	________
Back of neck	_____	________	________	________	________	________
Back of neck	_____	________	________	________	________	________
Back of neck	_____	________	________	________	________	________

Two-Point Discrimination Threshold (mm): _______

Briefly explain the physiology behind your findings (1-2 sentences).

c. Weber's Law

In the table below, fill in each test weight tested and state (yes/no) whether the test weight could be differentiated from the reference weight. Then calculate dI/I for both 100 and 200 g weights.

Test Weight	Differentiated from 100 g?			Test Weight	Differentiated from 200 g?		
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______
___________	______	______	______	___________	______	______	______

dI = ___________ dI = ___________

dI/100 = ___________ dI/200 = ___________

Do your data support Weber's Law? Explain briefly.

d. Temperature Receptors

When the hands were placed in warm and cold water (part i), what happened to the sensation of cold or warmth in each hand after 1 minute?

Did the subject adapt faster to the cold or hot water (part i)?

What sensation occurred when the hand from ice water was placed in room temperature water (part ii)?

What sensation occurred when the hand from hot water was placed in room temperature water?

Based on these last 2 observations, is the response of thermoreceptors at a given temperature influenced by the recent history of the hand’s thermal environment?

EXPERIMENT 2: HEARING

a. Auditory Acuity

Distance the watch is moved away from the ear
before the sound is no longer heard. _______________

Distance the watch is moved toward the ear
before the sound is first heard. _______________

Does the subject hear an approaching sound better or worse than a sound moving away?

There are two trains, A and B, 1 mile from a station. One train is coming into the station, and the other is leaving. Both trains have whistles blowing continuously, but only the whistle of Train A can be heard from the station. Which train is entering the station, and which is leaving?

b. Localization of Sound

With both ears open, is the judgment of direction better in the median plane or at the side of the head?

In the median plane, is the judgment more accurate above the head or in front of it?

What happens to the ability to localize sound when one ear is closed? Explain briefly.

c. Auditory Adaptation

What happens when the pinched tube is opened? Explain.

d. Weber Test

Record the subject's sensation of hearing: is the sound is heard equally in both ears? If not, then which side hears better?

e. Rinne Test

Fill in the data for both ears.

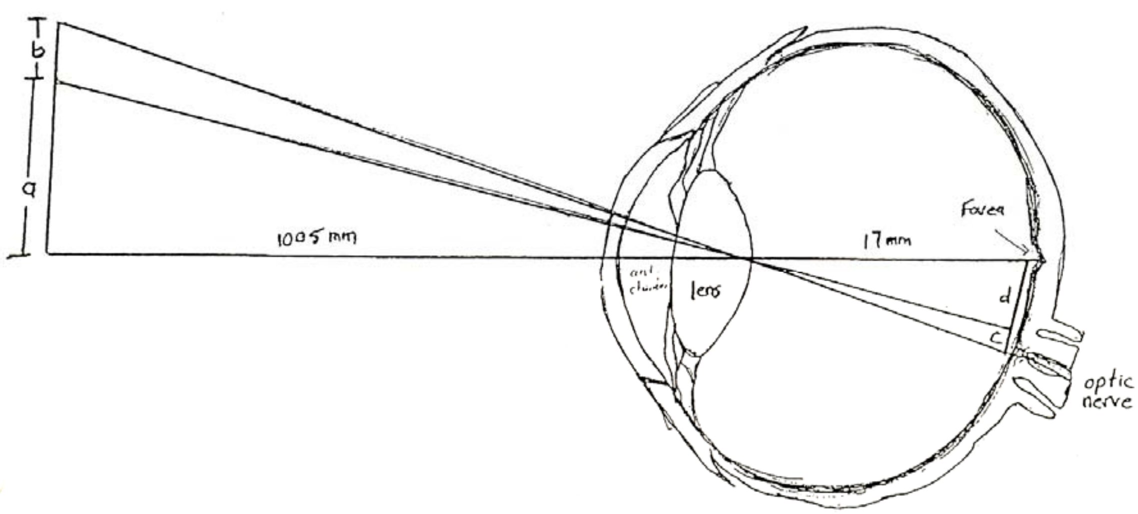
	Left Ear (s)	Right Ear (s)
With the tuning fork on the mastoid bone, how long does the subject perceive the sound?	____________	____________
With the tuning fork 1-2 cm from the auditory canal, how long does the subject perceive the sound?	____________	____________

Based on your examination of the subject (both the Weber and Rinne tests), are the results suggestive of normal hearing, conduction deafness, or nerve deafness? Explain, keeping in mind that we are not professional audiologists and that the testing environment is not optimal.

EXPERIMENT 3: VISION

a. Mapping the Blind Spot

Referring to the diagram below, determine the diameter of the optic disk. Follow the steps below the diagram.



a = distance from tape to near edge of blind spot = ____________ mm

b = width of blind spot = ____________ mm

d = distance from fovea to near edge of optic disk

$$\frac{d}{17\text{ mm}} = \frac{a}{1005\text{ mm}} \qquad d = \frac{(17\text{ mm})\,a}{1005\text{ mm}} = \_\_\_\_\_\_\_\_\_\_ \text{ mm}$$

c = diameter of optic disk

(d + c) = distance from fovea to far edge of optic disk

$$\frac{(d + c)}{17\text{ mm}} = \frac{(a + b)}{1005\text{ mm}}$$

$$(d + c) = \frac{(a + b)\,(17\text{ mm})}{1005\text{ mm}} = \_\_\_\_\_\_\_ \text{ mm}$$

(d + c) - d = c = diameter of optic disk = ____________ mm

Will the size of the visual blind spot increase or decrease at longer distances? ________________

b. Visual Acuity

What is the visual acuity index for the subject's right eye? __________________

What is the visual acuity index for the subject's left eye? __________________

c. Astigmatism

Did your test indicate astigmatism? __________________

d. Dominant Eye

What is the subject's dominant eye? __________________

Is the subject right- or left-handed? __________________

e. Negative After-Image Describe and explain your observations (briefly).

f. Depth Perception Compare the accuracy of fingertip touching with both eyes open, left eye open, right eye open and both eyes shut.

g. Retina Anatomy Did you observe blood vessels? Describe their structure.