Perception Lab #4: Receptor Density Mapping

Background

Humans learn a great deal about their immediate environment from the sense of touch. The brain is able to determine where the body has been touched, and can often identify the object that touched it, because it contains a kind of map that reflects the relative number of touch receptors in various parts of the body.

Human skin contains several different sense receptors that respond to mechanical and thermal stimuli (e.g., touch, pressure, pain, cold, heat). These receptors are used to help us explore and determine the characteristics of our external environment. We will discuss these receptors during the Monday lecture. (See Figure 3).

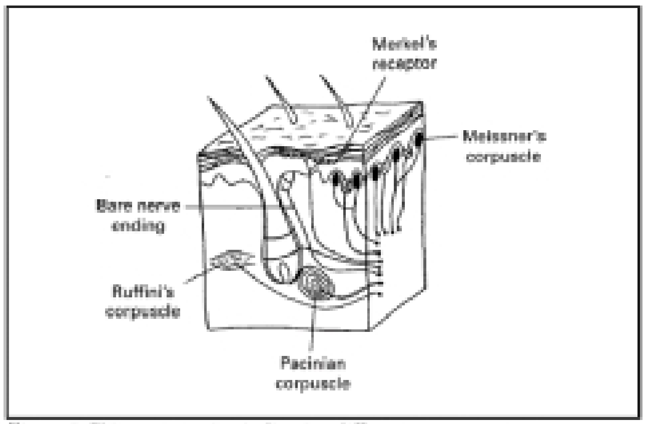

Figure 3. Skin cross section indicating different sense receptors.

A sense receptor is a specialized cell that transduces (converts) a physical or chemical stimulus into an electrical signal called an **action potential**. These action potentials produced by the receptors are conducted to the spinal cord and brain for processing and interpretation. The message that is sent to the central nervous system (CNS) is always a train of action potentials, regardless of the kind of stimulus that excites a particular receptor.

Sensory receptors that respond to touch on each side of the body send action potentials through axons that enter the dorsal columns of the spinal cord and ascend to the medulla (a part of the brainstem). These axons then make connections (synapses) with another pathway within the medulla. It is here that the pathways from each side cross over the brain midline and then continue to an area on the opposite side of the brain called the thalamus. The final pathway begins there and continues to the specific region of the sensory cortex, as shown in Figure 4. This pathway effectively gives one side of the brain responsibility for the opposite side of the body. This phenomenon is observed when a head injury or disease of the right side of the brain leads to physiological problems in a patient's left side.

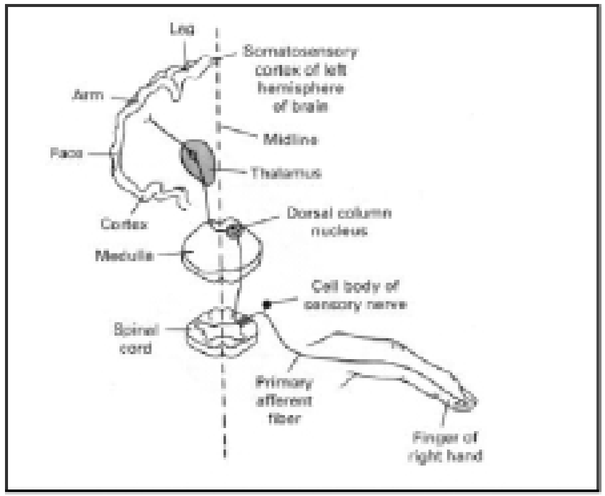

Figure 4. A schematic diagram showing how touch information from the finger is carried to the sensory cortex.

Most of the information about touch is centered in a thin, convoluted surface layer of the cerebrum of the human brain called the somatosensory cortex. Each point on this band of sensory cortex contains densely packed cells that correspond to sensory receptors from different parts of the body, as shown in Figure 5. The specific amount of space on the somatosensory cortex of the brain that is dedicated to sensing each body part is proportional to the density of the sensory receptors in that particular body region. For example, relatively few receptors are located in the upper arm; therefore, the upper arm area in the somatosensory cortex is small. In contrast, the density of receptors in the lips is very high, so the lip area of the cortex is large. The two-point discrimination method of this laboratory exercise can be used to approximate a map of the entire body as “sensed” by the cortex. The “picture” of the body on the somatosensory cortex is called the “homunculus,” which means “little person.”

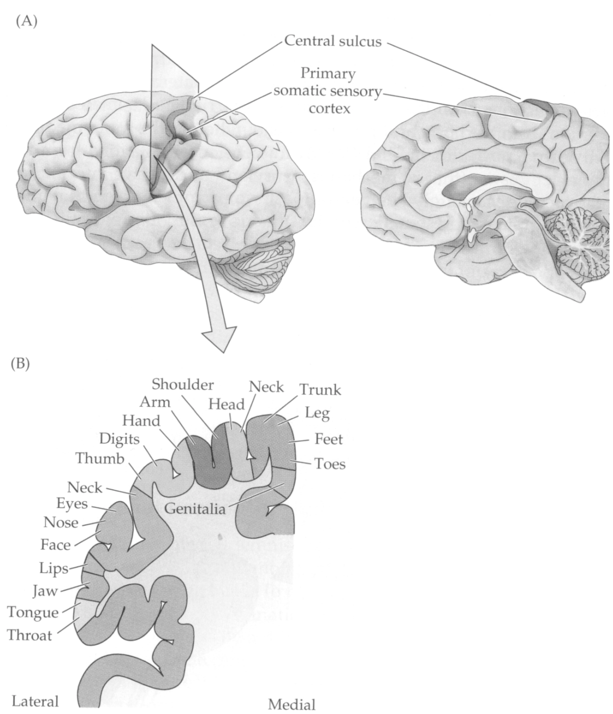

Figure 5: A: Diagram indicating the region of the human brain and the location of the somatosensory cortex.
B: Diagram (along the plane indicated in A) showing the somoatopic representation of body parts.

The two-point discrimination method determines the minimum distance that can be sensed between two points of touch. This technique can be used to determine the approximate size of the receptive field that senses light touch. In this procedure the two points of a caliper lightly touch the skin at the same time and the subject is asked to determine whether two points of the stimulus are felt or one. Two points placed on the tips of the fingers can be distinguished as two separate points even when the points are as close together as two millimeters. In contrast, on the subject's back the points must be about 40 millimeters apart before they can be identified as two separate stimuli (Martin & Jessell, 1991, p. 346). The discrimination of the finger is better than the back because the finger has a much larger number of specialized touch receptors than the back or other regions of the body.

The size of the head and body representation in the somatosensory cortex differs among species of mammals. In primates and carnivores, for example, the somatosensory representation of the paws, hands, and feet is large compared to the rabbit (Adey & Kerr, 1954; Adrian, 1941; Crosby, Humphrey & Lauer, 1962; Kandel & Jessell, 1991; Mickle & Ades, 1952; Woolsey & Wang, 1945). Most likely these regions of the body contain a large number of touch receptors. These distributions in primates and carnivores probably reflect how they hunt, collect, and handle their prey and other food. The rabbit has a large distribution for the face and snout because it uses them as the primary means for exploring the environment. The hand is well represented in all primates, but the thumb region is the most important in the toolmaking humans.

Touch sensors are found throughout a person's body. You may wonder why they are not normally aware of the touch caused by everyday stimuli such as your clothes or a watch on your wrist. These touch sensors are designed to be excited for a short period of time. After a while they do not respond any more to the constant stimulation; in other words, they adapt to a stimulus. This is quite similar to what we discussed in class regarding olfactory fatigue and retinal fatigue (after images). The receptors respond initially to a stimulus and than adapt or reset themselves. If the touch is changed slightly by movement or the touch shifts a bit on the skin, the sensors again become responsive for a short period of time.

Regions in the brain corresponding to touch receptors on the skin can be reconfigured when the area of the body they are responsible for is missing, as in amputation. In doing this, the brain may remodel the sensory neurons and they will be used as additional mapping in the brain for another area. The mechanism by which this happens is still not clearly understood.

Procedure

Part I: Work in pairs. One person should act as the subject while the other is the experimenter and data recorder. Examine the data sheet (last page of handout) before beginning, to familiarize yourself with the areas of the body you will be testing.

The subject will need to be blindfolded for this experiment. The experimenter will very lightly touch the skin at one of the areas listed in Table 1 with one or both of the points of the calipers. When both points are used, they should touch the subject *simultaneously*. At each touch the subject will report whether they feel one or two points touching their skin.

1. Begin with the calipers sufficiently separated so that all double stimuli are perceived as "two," then 'bracket the target,' A good beginning point is about **50 mm (5 cm)**.

2. The experimenter should gently place the points of the caliper on the subject's skin and ask the subject if he/she feels just one point or two.

3. The experimenter should pick either the left or the right side of the body to test. For each area of the body tested, the experimenter should try 10 times. If the subject correctly identifies 8 out of the 10 (i.e. as either one or two points), decrease the separation of the calipers to a value midway to the next smaller separation that was used. For example, if you began at 2 inches and the subject correctly identifies 8 out of 10, decrease the caliper distance to 1 inch and repeat.

4. Continue reducing the separation to one half of each previous separation until **8 out of 10 reports are incorrect.**

5. Record the distance (in mm) in which 8 out of 10 are **incorrect** in Table 1. This number indicates the 2 point discrimination threshold.

6. Repeat 1-5 for each area of the body listed in Table1.

Two-Point Discrimination	Reciprocal (1/measurement)
Example 2 mm	.5
Scalp	
Forehead	
Cheek	
Nose	
Chin	
Front of Neck	
Back of Neck	
Upper Back	
Shoulder	
Upper Arm	
Elbow	
Forearm	
Wrist	
Back of Hand	
Palm of Hand	
Tip of Thumb	
Tip of Index Finger	
Tip of Third Finger	
Tip of Fourth Finger	
Tip of Fifth Finger	
Front of Knee	
Back of Knee	
Lower Leg	
Back of Lower Leg	

Part II: Calculations.

The measurement recorded for each body part represents the distance between each sensory receptor field, so the distance measured is inversely proportional to the cortical area dedicated to that body part. That is: the closer the receptor fields, the larger the area on the cortex.

Each person should use the data to calculate the reciprocal of each measurement to estimate the relative number of touch receptors in various areas of skin. You should calculate the reciprocals by dividing each measurement into 1. For example, if the measurement is 2.0 mm, its reciprocal is 1 ÷ 2.0 = 0.5; if the measurement is 5 mm , its reciprocal is 0.2; if the discrimination is 1.0 mm, the reciprocal is also 1.0). The data recorder should enter the reciprocals into Table 1.

1. Draw a proportional picture of your homunculus on graph paper. If the inverse is 4.0, then the body part occupies 4 boxes on the graph paper, approximating the normal body shape. To enlarge the scale, for example, just multiply all values by the enlarging factor. For example, to make the drawing 5 times larger, multiply the inverses by 5. Your drawing doesn't have to be a work of art but should indicate the amount of the somatosensory cortex dedicated to specific regions of the body.

2. Which side of the brain's sensory cortex did you map? Explain.

3. How does your homunculus compare with those drawn by others? Discuss the similarities and differences.

4. With your lab partner, discuss the difference between an explanation in terms of adaptation (like Sacks) and one in terms of evolution (like Stoddart). Each of you should then write your own version of this difference in your lab notebook. Then, pick 3 of body areas you tested and for each, try to work out an adaptive or evolutionary value for the distribution of the receptors.