Sensory Physiology

The aim of this experiment is for students to familiarize themselves with their senses, sensory and related phenomena, and some sensory illusions.

Written by staff of ADInstruments.

Background

Conventionally, there are five senses: sight, hearing, taste, smell and touch (visual, auditory, gustatory, olfactory and tactile senses respectively). This is clearly an oversimplification. Additional sensory modalities include temperature, pain, vibration, joint position and proprioception.

Required Equipment

Pins and paper clips
Piece of white paper
Black felt-tip pen
Small flashlight
Three small buckets
Hot, cold and lukewarm water
Apple
Potato (raw)
Onion (raw)
Table sugar
Table salt
Citric acid (orange or lemon)
Cotton balls
Swivel chair

Procedures

Exercise 1: Convergence of gaze

Binocular vision requires that the separate images in the right and left eyes be 'fused' to give a single view. Fusion of the images of an object is possible only if the images fall on corresponding parts of the right and left retinae. If they do not, a double view of the object results.

1. Hold one arm outstretched, with the index finger upright and in line with some distant object (for example a clock on a far wall). Look at the finger (keep it in focus), but concentrate all attention on the distant object. Note that the distant object is seen doubled: there are two images, side by side.

2. Cover the right eye. Note that the right image of the distant object disappears.

3. With both eyes open, look at the distant object. Note that your finger is seen doubled.

4. Cover the right eye. Note that the left image of your finger disappears.

5. Ask a volunteer to look first at a distant object, and then at an object held close up (15 cm from the face). Note that the volunteer's eyes are turned inwards when looking at a close object.

Exercise 2: Accommodation (focusing)

The eye can accommodate (change focus) for far or near vision, by varying the shape of the lens.

1. Cover or close one eye, and hold a pin about 15 cm in front of the other eye, in line with some distant object.

2. Look at the distant object and note that the pin appears blurred and dim: it is out of focus.

3. Now look at the pin. Note that the distant object becomes dim and indistinct. Note also that accommodation for the near object (the pin) is accompanied by a feeling of effort.

4. Cover one eye and hold the pin at arm's length. While looking at the point of the pin, slowly bring it toward the face until it becomes blurred. The shortest distance at which the pin can be kept in focus is the 'near point'.

Exercise 3: The blind spot

The visual field for each eye includes a blind spot, representing the optic disc — a part of the retina with no photoreceptors.

1. Obtain a pen that writes with black ink but has a white barrel. Alternatively, wrap some white paper around the barrel of a black fiber-tipped pen, leaving only the black writing tip exposed.

2. Mark a small cross on a piece of white paper. Close the left eye and look steadily at the cross, at a distance of about 25 cm. For the rest of this exercise, keep the head completely still and continue to look at the cross.

3. Move the pen out (to the right) from the cross. At a certain distance the tip will become invisible. Mark this place with a spot on the paper.

4. Carry the pen further to the right, until it becomes visible again. Mark this place with another spot.

5. Similarly, mark the upper and lower limits of the blind spot.

Exercise 4: Mechanical stimulation of the retina

The eye has properties similar to those of a camera, in that the image formed on the retina is inverted. Light falling on the retina on one side of the eye gives a visual response in the opposite side of the visual field. Mechanical stimulation of the retina, by pressure on the eyeball, also gives a visual response that is inverted.

1. Turn ones gaze to the left, and shut both eyes. Keep looking to the left.

2. With a fingertip, press *gently* on the right side of the right eyeball, at the corner of the eye. Note the visual effect.

3. Slide a finger up and down, and note the direction of movement of the visual response.

4. Turn ones gaze to the right, and similarly press on the left side of the right eyeball, at the corner of the eye. Again, note the visual effect.

The main visual response to stimulation is a bright circle or disc, on the opposite side of the visual field from the site of stimulation. Stimulation of the retina on the right side of the eye gives a response on the left, and vice versa.

Exercise 5: The positive after-image

Retinal photoreceptors have a surprisingly long and slow response to light. A brief visual stimulus gives rise to a response that outlasts the stimulus long enough to give an after-image.

1. Face a bright scene, such as a sunlit window or a strongly illuminated bench-top.

2. Close both eyes and cover them with your hands. Wait for 30 seconds.

3. Remove your hands, and open the eyes for the shortest possible time, then close them again.

4. Note the after-image. Bright features of the scene remain visible for an appreciable time (a substantial fraction of a second).

Exercise 6: The negative after-image

The sensitivity of retinal photoreceptors decreases gradually while they are being stimulated by light, and increases while they are not. This adaptation to light and dark allows visual function over a very wide range of light intensities. It has the side effect of giving rise to negative after-images.

1. Place a black object on a piece of white paper, or draw a black square on the paper.

2. Look fixedly at the black object for 30 seconds. The volunteer may blink, but should take care to keep their gaze fixed.

3. Shift the gaze to a piece of plain white paper, and note the after-image of the black object. The image lasts for many seconds. The image is inverted in contrast (the black object gives a bright after-image), hence the name 'negative after-image'.

4. Repeat with a colored object, and note the color change in the after-image. For example, a red object gives a green after-image.

Exercise 7: Retinal blood vessels

The blood vessels of the retina lie *in front* of the neural and photosensitive layers. Absorption and scattering of light by the retinal vessels would be expected to give rise to an image. This image, however, is normally suppressed by poorly understood mechanisms. Altering the direction of illumination of the vessels temporarily overcomes this suppression, and makes the image visible. Sufficient light can enter the eye through the sclera (the "white" of the eye) if a small, bright light source is held close to the eye in such a way that little light enters via the pupil.

1. Shut both eyes and direct the gaze to the left. Shine the beam of a small torch on the eyelid at the right side of the right eye. Hold the torch close to the eye, so that it forms a small bright illuminated spot.

2. A lacy network pattern should be visible for a short time, although it then fades. Moving the torch slightly restores the pattern. Continuous rhythmic movement of the torch keeps the image visible.

3. The vessels may be seen more clearly if the eyes are open and the torch is directed at the sclera directly. This requires, however, either that the experiment is done in a darkened room, or that the subject looks at a featureless scene, such as a plain dark-colored wall.

4. With patience, the branching zigzag pattern of the vessels can be clearly seen. The center of the visual field has no blood vessels passing across it. Vessels approach, in a radial direction, from outer parts of the field.

5. Most people can see the origin of the branching pattern of vessels, in a small region to the right of center. This is the optic disk (see Exercise 3).

Exercise 8: Two-point discrimination

The density of tactile receptors in the skin differs greatly in different parts of the body.

1. Take a metal paperclip and unfold it. Bend it into a U shape, with the wire points about 10 mm apart.

2. Touch the two points gently on the palm of a volunteer's outstretched hand, and ask if one point or two is felt. With a separation of 10 mm, the double stimulus from the two points can be easily felt.

3. Ask the volunteer to close both eyes. Bend the paperclip so as to bring the points closer together. By repeated trials with different point separations, find the smallest separation that the volunteer can distinguish as two points. Test the truthfulness of the volunteer's responses, from time to time, by turning the paperclip slightly, and pressing only one of the points down.

4. Measure the separation of the points with a ruler.

5. Repeat steps 3 and 4 with trials on different parts of the body (for example, a finger tip, the back of the hand and the back of the forearm).

Exercise 9: A tactile illusion

1. Cross two adjacent fingers over, so that the fingernails lie side by side, but in a position reversed from the normal. Most people find it easiest to cross the middle finger over the index finger.

2. Place a small object such as a pen in the V-shaped gap between the two fingernails, and gently move it back and forth.

3. Note your sensations.

Exercise 10: A thermal illusion

Many sensory systems show adaptation: a declining response to a continued steady stimulus. Temperature sensors in the skin adapt in this way, and so thermal sensations of warmth or cold are determined more by changes in temperature than by the temperature itself.

1. Obtain three containers (small buckets or large beakers). Fill one container with hot, but not painfully hot, water. Fill another with cold water, and fill the third with lukewarm water.

2. Place one hand in hot water and the other hand in cold water. Leave them there for 30 seconds.

3. Now place both hands in the lukewarm water. Note any sensations.

Exercise 11: Taste and smell

Both taste and smell use chemoreceptors. A large component of taste is actually due to olfaction (smell).

1. Ask a volunteer to close their eyes and to pinch the nostrils together, preventing airflow through the nose.
2. Place a small previously prepared piece of apple in the volunteer's mouth, and ask them to try to identify it by taste.
3. Repeat with a piece of raw potato, and then with a piece of raw onion. Identification is extremely difficult.
4. Repeat steps two and three, but this time allow the volunteer to breathe through the nose. Identification is now easy.

Exercise 12: Distribution of taste buds

Taste receptors ("taste buds") are found principally on the tongue, but also on the palate and pharynx. Four kinds of taste bud are recognized: sweet, sour, salt and bitter. Each kind of taste bud has a characteristic spatial distribution on the tongue.

1. Prepare or get small beakers of the following solutions:
   a) Sucrose (table sugar): approximately 15 g in 50 mL water.
   b) Sodium chloride (table salt): approximately 5 g in 50 mL water.
   c) Citric acid: approximately 2 g in 50 mL water.
2. Dip a small piece of clean cotton wool or the end of a cotton bud in the sucrose solution, then shake off the excess solution.
3. Apply the cotton to the back of a volunteer's tongue, and ask the volunteer to report the sensation. Discard the cotton wool or bud.
4. Using a fresh piece of cotton wool or new cotton bud, test the sensitivity of one side of the tongue. Similarly, test the tip of the tongue.
5. Repeat step two, but with the salt solution. Note the distribution of salt sensitivity.
6. Repeat step two, but with the citric acid solution. Note the distribution of sour sensitivity.

Exercise 13: The "joint position" sense

The capsule and ligaments of a joint receive a sensory innervation that is able to detect changes in joint position. The effectiveness of this little-known sense is easily demonstrated.

1. Ask a volunteer to hold out one hand with the palm facing up and the fingers stretched out.
2. Hold the volunteer's index finger by placing your thumb on one side and your index finger on the other. Don't hold the volunteer's finger by the front and back; that could give cues about movements, deriving from the force of lifting or pulling down.
3. Bend the volunteer's finger up, while saying "This is up". Then pull the finger down to the original extended position, while saying "This is down".
4. With the volunteer's eyes shut, test their ability to identify the direction of a series of finger movements. Try both large and small movements.

Exercise 14: The semicircular canals

The semicircular canals are liquid-filled channels in the temporal bone of the skull, and form part of the inner ear. They detect rotary movements of the head in three axes. This exercise requires a swivel chair or a stool that can be rotated smoothly on its vertical axis.

1. The volunteer should sit on the swivel chair, with both feet in the air, and close both eyes.

2. Ask the volunteer to say when a rotation is detected, and to indicate in which direction. Test the volunteer's ability to sense rotary motion, by rotating the chair at various speeds and for various durations. Very slight movements are reliably detected.

WARNING: Take care that the volunteer does NOT stand immediately after spinning. The volunteer should be assisted out of the chair after a few minutes recovery from the chair spinning.

The semicircular canals detect rotation but do not signal the body's position. Test this by showing that the volunteer's idea of which direction they are facing becomes unreliable after a sequence of rotations, such as a quarter-turn in one direction and then a half-turn in the other. However, the test is not straightforward to do, because the volunteer will make use of other directional cues. The ambient light intensity may change with rotation, and this can be sensed even through closed eyelids. Acoustic cues are also likely to be present in many laboratories

Data Notebook

Record observations for each exercise in the spaces below.

Exercise 1: Convergence of gaze

Exercise 2: Accommodation (focusing)

Exercise 3: The blind spot

Exercise 4: Mechanical stimulation of the retina

Exercise 5: The positive after-image

Exercise 6: The negative after-image

Exercise 7: Retinal blood vessels

Exercise 8: Two-point discrimination

Exercise 9: A tactile illusion

Exercise 10: A thermal illusion

Exercise 11: Taste and smell

Exercise 12: Taste bud distribution

Exercise 13: The “joint-position” sense

Exercise 14: The semicircular canals