

The Handy Guide to Touch **By Elise Hancock**

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When you stroke something—ice, a raised letter A, a baby’s silky rump—how are the various sensations produced? Why are some pleasant, others not? How do you recognize the A as A?

“Touch is the least understood sense,” says Kenneth Johnson, an engineer turned neurology researcher. A specialist in touch, Johnson is professor of neuroscience and biomedical engineering, doing his research at Hopkins’s Krieger Mind/Brain Institute. The magazine is indebted to him, as well as to his Krieger colleague Steven Hsiao, for their help with this hop-skip-jump through some high points of touch, that most intimate and mysterious of senses.

The human hand contains about 100,000 nerves, of at least 20 different kinds. Twelve receive various touch sensations; eight are motor fibers, carrying commands from the spine; and all are specialists—

In reporting joint and muscle activity, for instance. Or pressure. Or temperature (hot and cold, separately). Or vibration (both high- and low-frequency).

And pain—several kinds of pain. For example, one set of pain receptors warns you of a cut, an entirely different set that the skillet is burning hot.

Dotted all over your skin are receptors that report warmth, and others that report cold—literally, “report cold.” If you poke the skin between your knuckles with a pencil or a ball-point pen, just hard enough to indent the skin, you will soon find a spot that gives a jolt of cold. That’s because the pencil is colder than the skin.

Note that this receptor only reports cold. In fact, even if you poke one with a hot point, the sensation remains one of chill. (Neurologists call that paradoxical cold.) Similarly, warmth receptors can only report heat.

Both can perceive a sudden change as small as a twentieth of a degree—but they quit at the point of tissue damage. If you touch something hot enough to burn (more than 45 degrees C), warmth receptors stop firing and specialized pain receptors take over. Then the brain jumps your hand off that pot so fast you won’t even have time to say “Ouch!”

Similarly with cold receptors: once the chill drops to frost-bite level, a set of pain receptors takes command. These produce a slow, burning pain; the faster the neurons fire, the more intense the pain.

The tongue, lips, and fingertips are the most touch-sensitive parts of the body, the trunk the least. Each fingertip has more than 3,000 touch receptors, many of which respond primarily to

pressure. These are packed in just under the surface of the skin, where each reports events in overlapping fields about one-tenth of an inch across. Hsiao says the entire trunk, by contrast, has about as many touch receptors as a single hand.

To get a sense of the practical effect, try a crude version of the traditional two-point acuity test: Using a compass or two pencils, press down two adjacent points on the skin, in a measured, consistent way. Try it on the inner wrist first.

How far apart do the points have to be before you feel them as two distinct points? (That means, being in two different neural fields.) For most people, on the wrist it's about an inch. On the back, far more. On the finger, less. And the lip and tongue, believe it or not, have nearly twice the spatial acuity of the finger.

Ongoing research by Robert Van Boven, a student of Ken Johnson's, uses a more precise and reliable acuity test in which people are asked to tell which way the bars run—horizontal or vertical—on a small grating. Using a finger, people can perform the task once the bars are .94 mm. apart (1 mm. = .04"). But the tongue has a threshold of .58 mm, and the lip is even more finely tuned—its acuity is sensitive to just .51 mm. Accordingly, in the part of the brain where raw sensory input first reaches the cortex, the patch devoted to neurons from the tongue is comparatively large.

Since this intake structure has a specific zone for every body part, it is sometimes called the "homunculus" (little man), in reference to old beliefs that little men resided in each human head, to make decisions, feel emotions, and so on. Lying about midway between the front of each ear and the crown of the head, on the outermost layer of the brain, this homunculus (really, the postcentral gyrus of the parietal cortex) was mapped at Hopkins some 60 years ago. Several similar homunculi have since been discovered, including one for the motor cortex.

When you touch something, what happens in the skin and homunculus is fairly straightforward: neurons fire. But what happens deeper in the brain is mysterious indeed. Take the simplest possible example—you are stroking your finger across a rather large A, which is raised as in braille. And you are going to recognize it as A, with no peeking.

As you stroke, the skin is indented, just ever so slightly, as it passes over the A. That causes several hundred neurons to fire, each one reporting pressure as a bit of the letter passes through its neural field. Johnson, Hsiao and colleagues can record these images from tiny probes in the wrist, with results that look like those above.

The nervous system is so well organized that all the information from one finger, or one part of one finger, stays together, and the "picture" of A travels up the nerve fiber through the arm. "It's the hand as eye," says Johnson. "You probably know that when the cones and rods in your retina fire, they produce a recognizable picture of whatever you're looking at? Well, this is like that. The finger sends off to the brain a picture that is exactly like the object itself. We call it isomorphic." (Iso = same, morphic = form.)

The flood of coherent signal goes to the spinal cord and is relayed to the brain stem, then the thalamus, and finally reaches the cerebral cortex for processing.

Finally, by the way, is the accurate word. “You can run faster than some nerve fibers transmit,” says Johnson (meaning pain and thermal ones). “In the brain, touch signals can move anywhere from one foot a second to 200 feet a second. Computers transmit much, much faster. Yet we recognize pattern in three to four tenths of a second,” which the computer cannot. In the end, says Johnson, “It’s the brain that is fast.” “A!” it says. “Oh, that’s easy–A!”

The mystery is, when the A image first reaches the cerebral cortex, neural recordings show it still looks like an A. But as sensory impulses fan out to deeper parts of the brain, they become more and more abstracted. Deep neural readouts, when they can be obtained, look chaotic.

“How do we know whether we’re touching an A or a B?” says Johnson. “The image must be stored in memory. The brain must compare it with others and say aha! that matches A!–that’s pattern-recognition. People do it magnificently. Machines do not.” In some way, says Johnson, the very abstractedness of memory’s template must be what makes it work. It’s an all-purpose tool.

Machines, by contrast, get hung up on all the thousands of differences among A’s: where the letter is placed on the paper, for instance. Whether it’s drawn by you, me, your first-grader, or a type-setting machine. Whether it’s big or little. Whether it’s crooked. Whether the paper is dirty. Whether the A has big curlicues, little ones, or none, or is printed on top of some other letter.

Not us: A-ness, sandpaper, fine flour, baby rump, Nylon carpet, your hair as opposed to anyone else’s hair—we humans can touch and know such patterns, it seems, in an instant. And we can do it even in variations we have never encountered, thanks to those abstracted templates. “The moment we understand how we do that,” says Johnson, “–like understanding DNA—we will understand the brain at an entirely new level.”

Elise Hancock is the magazine’s senior editor.