BIOSENSORS

A touching discovery

Fake fingertips provide insights into how fingerprints help humans to feel fine details of surface texture.

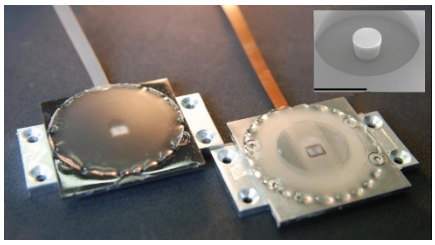
Although they may not be aware of it, a blind person scanning their finger across a page of Braille is simultaneously making use of two distinct classes of touch receptors—'coarse' sensors that recognize the relatively large embossed dots and 'fine' sensors that detect the far subtler texture variations in the page itself.

This general principle has been recognized for the better part of a century, but only in recent years have scientists experimentally characterized the processes involved. It turns out that whereas gross textural variations are detected by pressure-sensitive mechanoreceptors, really fine details—defects at the scale of a few hundred micrometers—are processed by specialized neurons known as Pacinian corpuscles, which detect tiny vibrations produced as skin brushes against a minutely irregular surface.

Some have hypothesized that fingerprint ridges also have a role in this process. "Propositions were made that basically fingerprints would act as magnifying levers," explains Alexis Prevost, a physicist at France's Ecole Normale Supérieure. He and colleague Georges Debrégeas were studying the interactions between soft and rigid materials, and realized that their work could provide a useful vehicle for investigating the contribution of fingerprints to tactile sensation.

They created a biomimetic fingertip analog, composed of a force-detecting microelectro mechanical system (MEMS) sensor covered by a thin hemisphere of polymeric 'skin', roughly recapitulating the arrangement of the Pacinian corpuscles, which lie approximately two millimeters beneath the skin. They then dragged this sensor across a glass slide that was textured with an uneven pattern of tiny ridges and valleys. "A major advantage of this approach is that you can easily put some fingerprints in and then take them out, and see directly what the difference is on the recorded signals," says Prevost, "which is something you cannot easily do with a real finger!"

Their findings, described recently in *Science*, demonstrate that the presence of a set of parallel, one-dimensional 'fingerprints' on the skin conferred a 100-fold amplification of the force generated as the sensor slid along the patterned glass, relative to the overall signal smoothing observed with a featureless sensor. The resolution of tactile sensation appears to be determined by the distance between fingerprint ridges and the scanning speed of the fingertip; in typical physiological conditions, the deformation of the fingerprint ridges is expected to produce vibrations of an ideal frequency for stimulating Pacinian corpuscles.



The biomimetic sensors used by Prevost and Debrégeas: one with smooth 'skin' (left) and one with 'fingerprints' (right). Inset, vibration-detecting component of the MEMS sensor. Scale bar, 1 millimeter. Image courtesy of A. Prevost.

This represents important progress toward resolving the enigma of how these cells, which have a relatively large receptive field of 2 square millimeters and should therefore offer poor spatial resolution, can provide detailed information about fine textures. "You'd expect to basically average out everything, and not see all the rapid fluctuations," says Prevost. "But by putting a fingerprint in front, you're generating an oscillating signal that you will be able to amplify and detect."

This model is obviously a simplification, but to Prevost's thinking, this is an advantage as well as a limitation, enabling them to study fundamental physiological phenomena while eliminating confounding noise produced by unrelated, external factors. Moving forward, he and Debrégeas plan to create more sophisticated biomimetics containing large arrays of sensors, which better recreate the complex sensory ecosystem of the skin. In the longer term, he believes that the principles outlined by this work could help give machines a 'human touch'. "We know this will definitely increase the sensitivity of robot hands," says Prevost.

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RESEARCH PAPERS
Scheibert, J. *et al.* The role of fingerprints in the coding of tactile information probed with a biomimetic sensor. *Science* **323**, 1503–1506 (2009).