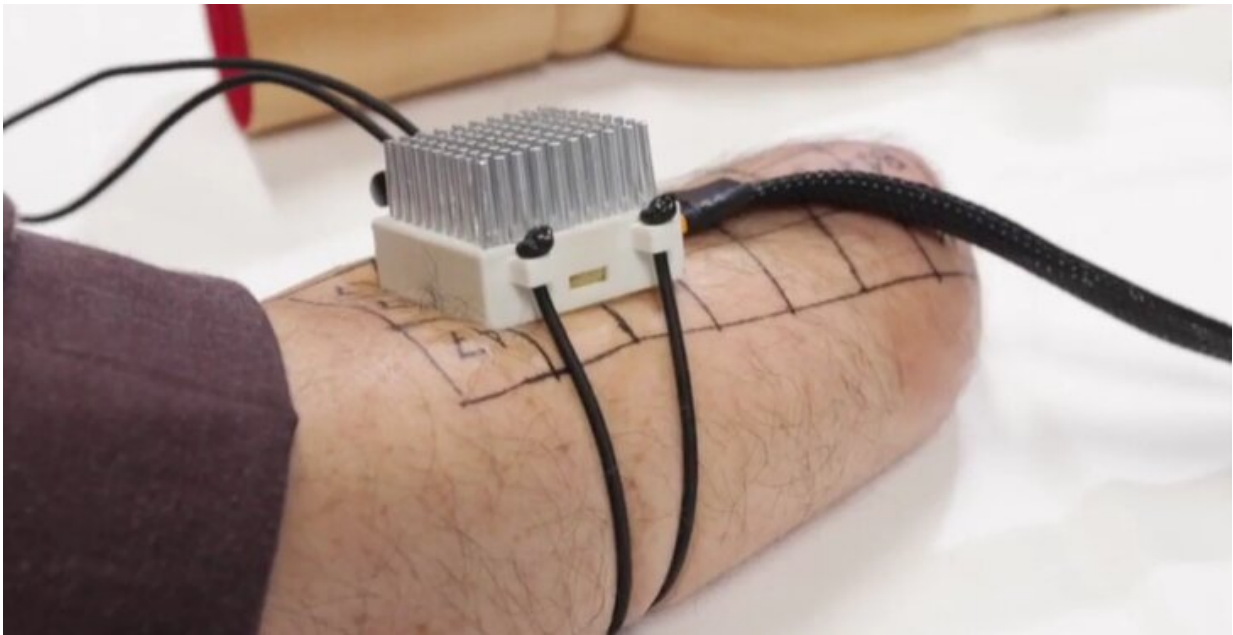


# Bionic prosthetics research: Amputees have thermal sense in missing limbs

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Credit: Ecole Polytechnique Federale de Lausanne

"When I touch the stump with my hand, I feel tingling in my missing hand, my phantom hand. But feeling the temperature variation is a different thing, something important... something beautiful," says Francesca Rossi.

Rossi is an amputee from Bologna, Italy. She recently participated in a study to test the effects of temperature feedback directly to the skin on

her residual arm. She is one of 17 patients to have felt her phantom, missing hand change in temperature thanks to new EPFL technology. More importantly, she reports feeling reconnected to her missing hand.

"Temperature feedback is a nice [sensation](#) because you feel the limb, the phantom limb, entirely. It does not feel phantom anymore because your limb is back," Rossi continues.

Researchers Silvestro Micera and Solaiman Shokur have been keen on incorporating new sensory feedback into [prosthetic limbs](#) for providing more realistic touch to amputees, and their latest study focuses on temperature. They stumbled upon a discovery about temperature feedback that far exceeds their expectations.

If you place something hot or cold on the forearm of an intact individual, that person will feel the object's temperature locally, directly on their forearm. But in amputees, that temperature sensation on the residual arm may be felt in the phantom, missing hand.

By providing temperature feedback non-invasively, via thermal electrodes (aka thermodes) placed against the skin on the residual arm, amputees like Rossi report feeling temperature in their phantom limb. They can feel if an object is hot or cold, and can tell if they are touching copper, plastic or glass. In a collaboration between EPFL, Sant'Anna School of Advanced Studies (SSSA) and Centro Protesi Inail, the technology was successfully tested in 17 out of 27 patients. The results are published in *Science*.

"Of particular importance is that phantom thermal sensations are perceived by the patient as similar to the thermal sensations experienced by their intact hand," explains Shokur, EPFL senior scientist neuroengineer who co-led the study.

## **Toward realistic bionic touch**

The projection of temperature sensations into the phantom limb has led to the development of new bionic technology, one that equips prosthetics with non-invasive temperature feedback that allows amputees to discern what they're touching.

"Temperature feedback is essential for relaying information that goes beyond touch, it leads to feelings of affection. We are social beings and warmth is an important part of that," says Micera, Bertarelli Foundation Chair in Translational Neuroengineering, professor at EPFL and SSSA who also co-led the study. "For the first time, after many years of research in my laboratory showing that touch and position information can be successfully delivered, we envisage the possibility of restoring all of the rich sensations that one's natural hand can provide."

## **Temperature feedback, from well-being to prosthetics**

A few years ago, Micera and Shokur got wind of a system that could provide temperature feedback through the skin of healthy subjects, also developed at EPFL and spun-off by Metaphysiks.

Metaphysiks has been developing neuro-haptic technology, MetaTouch, which connects the body with digital worlds. MetaTouch combines touch and temperature feedback to augment physical products for well-being.

"This breakthrough highlights the power of haptics to improve [medical conditions](#) and enhance the quality of life for people with disabilities," says Simon Gallo, Co-founder and Head of Technology at Metaphysiks.

The EPFL neuroengineers borrowed MetaTouch that provides thermal feedback directly to a user's skin. With this device, they discovered the

thermal phantom sensations and subsequently tested it in 27 amputees.

## **The Minitouch prototype and tests**

For the study, Shokur and Micera developed the MiniTouch, a device that provides thermal feedback and specifically built for integration into wearable devices like prosthetics. The MiniTouch consists of a thin, wearable sensor that can be placed over an amputee's prosthetic finger. The finger sensor detects thermal information about the object being touched, more specifically, the object's heat conductivity.

If the object is metallic, it will naturally conduct more heat or cold than, for instance, a plastic one. A thermode, one that is in contact with the skin on the amputee's residual arm, heats up or cools down, relaying the temperature profile of the object being touched by the finger sensor.

"When we presented the possibility to get back temperature sensation on the [phantom limb](#) or the possibility to feel the contact with different materials, we obtained a lot of positive feedback. And eventually, we were able to recruit more than 25 volunteers in less than two years," says Federico Morosato who was responsible for organizing the clinical aspect of the trials at Centro Protesi Inail.

The scientists found that small areas of skin on the residual arm project to specific parts of the phantom hand, like the thumb, or the tip of an index finger. As expected, they discovered that the mapping of temperature sensations between the residual arm and the entire projected phantom one is unique to each patient.

## **Bionic prosthetics for repairing the human body**

Almost a decade ago, Micera and colleagues provided real-time sensory

feedback about objects being grasped. They went on to improve touch resolution by providing feedback about an object's texture and position information in a reliable way. Moreover, they discovered that amputees begin to embody their prosthetic hand if provided with sensory feedback directly into their intact nervous system.

The added sensation of temperature [feedback](#) is yet another step towards building bionic prosthetics for repairing the human body. Fine-tuning temperature sensations and integrating these into a wearable device that can be mapped out to each patient are part of the next steps.

**More information:** Francesco Iberite et al, Restoration of natural thermal sensation in upper-limb amputees, *Science* (2023). [DOI: 10.1126/science.adf6121](#).  
[www.science.org/doi/10.1126/science.adf6121](http://www.science.org/doi/10.1126/science.adf6121)

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