Eyes of tomorrow: Smart contact lenses lead the way for human-machine interaction

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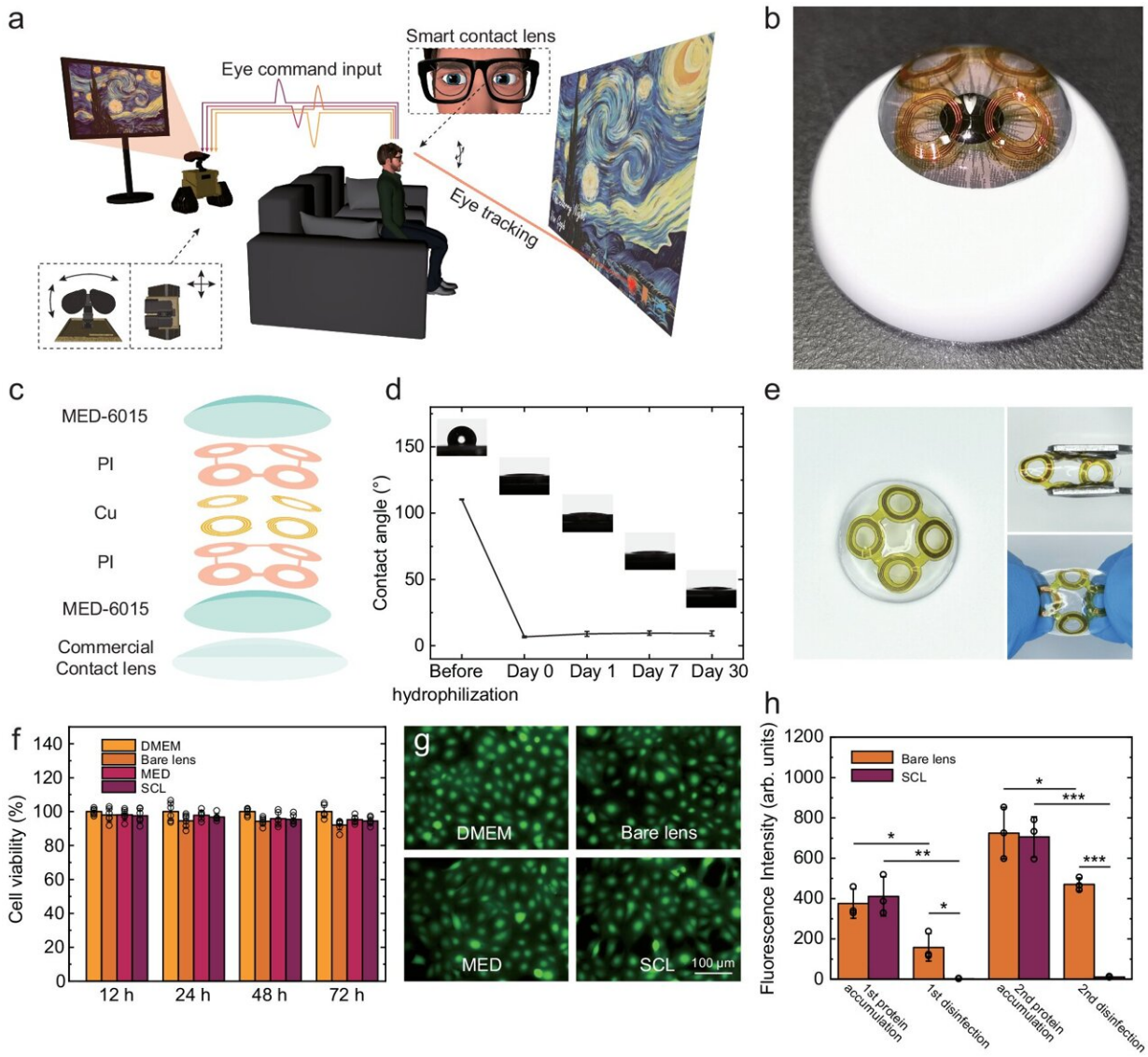

Human-machine interaction by eye-tracking using smart contact lens. b) shows a photograph of the lens. Credit: *Nature Communications* (2024). DOI:

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Scientists from Nanjing, China, have developed eye-tracking smart content lenses based on radio frequency tags that can be used for various applications, including health care and augmented reality (AR). The lenses are biocompatible and imperceptible, requiring no battery or conventional silicon chips.

Smart contact lenses that can keep track of various health factors and can be used for human-machine interaction (HMI) are a relatively new technology. These rely on tracking eye movements using methods like pupil center corneal reflection and electrooculography (EOG).

While these methods have shown some success, they lack accuracy and are susceptible to interference. Additionally, EOG, which uses skin electrodes for collecting data, has been shown to pose a risk to the skin.

The new study published in *Nature Communications* aims to overcome the challenges posed by traditional eye-tracking methods.

One of the co-authors of the study, Prof. Fei Xu from the College of Engineering and Applied Sciences at Nanjing University, spoke to Tech Xplore about the work. Speaking of what inspired him to develop smart contact lenses, he spoke about how science fiction can drive scientists' imaginations and creativity.

"Mission: Impossible 4 proposed a smart contact lens with a facial recognition function. If small contact lenses can achieve a seamless combination of the virtual and real worlds, it will be the ultimate form of AR technology. The human-computer interaction technology based on eye tracking is one of the more important components," he said.

Human-machine interaction

The interaction of humans and machines is the next step or challenge in the technological world, and HMI is at the heart of this. HMI is a study of how humans and machines interact and how to make this communication smoother and more efficient.

It has the potential to impact several domains, including gaming, health care, AR, and robotics. Eye-tracking using smart contact lenses is one of the ways in which we can facilitate HMI.

It can help to monitor various health parameters, make it easier to communicate with robots, and give a more immersive AR experience. However, as mentioned before, present eye-tracking methods have challenges, which has required scientists to take a new approach.

The researchers propose a frequency-encoding approach to overcome these challenges.

Frequency-encoding

The frequency encoding method used by the researchers for the smart contact lens involves encoding information about eye movements into radio frequency or RF signals.

The RF signals are generated by RF tags which have been embedded within the contact lens. RF tags, which are also known as RFID chips, are also used in things like credit cards. They are completely wireless and require no battery source to work, making them ideal for eye-tracking applications using contact lenses.

Each tag emits a unique frequency signal corresponding to different eye movements or positions. As the eye moves, the relative positions of the

RF tags change, which alters the frequency of the emitted signal.

By detecting and analyzing these frequency changes, the system (or machine) can determine the direction and extent of eye movements in real time.

This frequency encoding strategy allows for precise and accurate tracking of eye movements without the need for conventional silicon chips or batteries, making smart contact lenses more compact, lightweight, and biocompatible.

Additionally, it is very secure.

Prof. Xu explained, "The implementation of this technology eliminates the possibility of the leakage of iris and other biometric information. Human eye information contains the attention mechanism of the human brain, and human intention can be analyzed by tracking eye movement. User authorization is required to use the eye-tracking information."

Making and testing the smart contact lens

The researchers used four RF tags and embedded them in a silicone elastomer. Silicone is what regular contact lenses are made from, making these smart contact lenses biocompatible. This setup was tested to minimize toxicity to the cornea, which could lead to corneal inflammation.

A portable sweeping frequency reader was kept nearby to record and analyze the signals from the RF tags (it serves as the machine part of HMI).

The researchers demonstrated that their smart contact lenses can detect gazing directions and real-time gazing points, which could be used for

robot control and software interaction.

Further, they showed that the lenses are very stable and can be worn for up to 12 hours in different environmental conditions. They have also shown that the lenses can detect eye closure.

One of the key aspects of these smart contact lenses is their high angular accuracy, which enables eye command recognition for broader HMI applications.

"Our eye-tracking contact lenses are highly accurate, with an eye movement angle accuracy of less than 0.5 degrees, even smaller than the viewing angle provided by the fovea. The fovea is the densest area of cones in the retina, providing high-definition imaging and where attention is focused," said Prof. Xu.

They also showed how eye commands can control games like Gluttonous Snake and can be used for web browsing. Moreover, they conducted in-vivo experiments in rabbits to verify the lenses' function and safety.

The smart contact lens is very similar to the commercially available contact lenses and was proven to be hydrated, safe, and biocompatible with the eye.

"In situ, eye tracking can be achieved through contact lenses, which are small and lightweight, not easy to detect, compatible with fashion, and do not affect interpersonal social interaction," added Prof. Xu.

Potential applications

Since the launch of the Apple Vision Pro, it has prompted researchers and the public to explore the potential applications of computer and human interaction using the eyes.

"Contact lenses are the ultimate form of AR. The seamless integration of the virtual world and the real world through contact lenses has been depicted in many science fiction works."

"With the development of optoelectronic technology and the improvement of the flexible integration of optoelectronic devices, contact lenses will realize more and more functions in human-computer interaction and medical health," concluded Prof. Xu.

This will not only promote technological innovation but have a positive impact on people's quality of life.

More information: Hengtian Zhu et al, Frequency-encoded eye tracking smart contact lens for human–machine interaction, *Nature Communications* (2024). DOI: 10.1038/s41467-024-47851-y