Closed-eye imaging can track wakefulness, awareness and pain in unresponsive conditions

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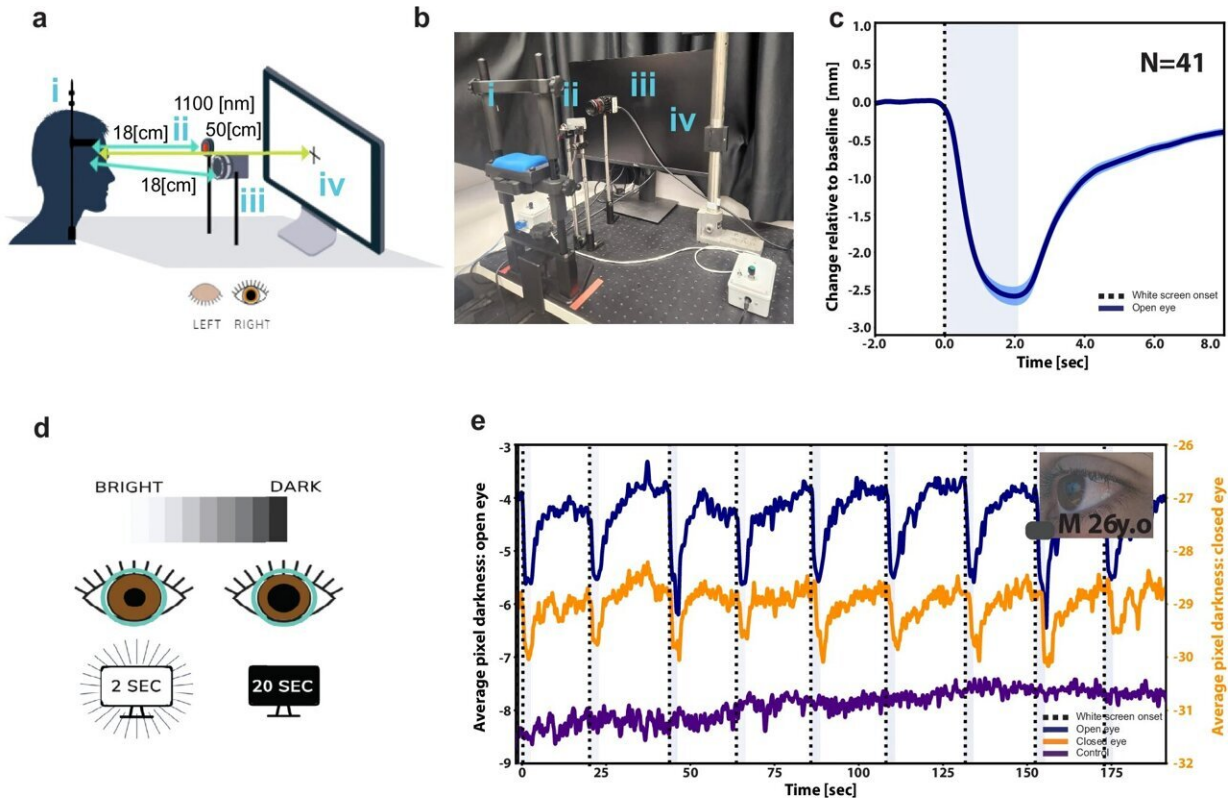

Pupillary light reflex (PLR) assessment in open-eye and closed-eye conditions. Credit: *Communications Medicine* (2024). DOI: 10.1038/s43856-024-00572-1

A new technological development allows researchers, for the first time,

to monitor changes in pupil size and gaze direction behind closed eyes using touchless infrared imaging. In the future, tracking changes in pupil size will help identify a state of wakefulness in sleep, anesthesia, and intensive care and help track the depth of sedation, detect seizures and nightmares, and recognize pain or responsiveness that may occur after trauma and in intensive care departments. The investigators anticipate that this technology has a strong potential to become an important tool in clinical care.

The breakthrough was achieved by a team of investigators from Tel Aviv University led by doctoral student Omer Ben Barak-Dror, under the joint supervision of Prof. Yuval Nir from the Department of Physiology, Faculty of Medical and Health Sciences, Sagol School of Neuroscience, and the Department of Biomedical Engineering; and Prof. Israel Gannot from the Department of Biomedical Engineering. Other team members include Dr. Michal Tepper, Dr. Barak Hadad, Dr. Hani Barhum and David Haggiag.

The research was published in the journal *Communications Medicine*.

Prof. Nir notes that "it is often said that the eyes are the windows to the soul." Indeed, pupil size changes all the time, dilating or contracting to regulate the amount of incoming light, while providing valuable clinical information. We all know that our pupils get smaller in bright light and larger in darkness. But this is only one reason why pupils change size. They also dilate when we're stimulated, for example when we react to a sudden event or when we are in pain. In such cases, our autonomic nervous system serves as an alarm and prepares us to take action.

Tracking pupil size and eye movements can be critical in many clinical situations. However, until now, this has been limited to open-eye scenarios. There was no method that allowed anyone to do this when the eyes are closed.

The new research describes innovative technology that combines short wave infrared (SWIR) imaging with deep learning algorithms to perform touchless pupillometry and eye tracking behind closed eyelids.

"To establish and validate our technology, we focused on the pupillary light reflex (PLR) when the pupil constricts in response to a sudden flash of light, and then dilates back to normal. This is a basic reflex that occurs symmetrically across the two eyes in healthy people. We performed experiments testing our technology on the closed eye while comparing the results to the open eye data," said Omer Ben Barak-Dror, lead author of the study at Tel Aviv University.

Profs. Nir and Gannot observe, "Our method can successfully track the precise dynamics of the pupillary light reflex in closed-eye conditions, revealing the changes in pupil size following each light flash in individual subjects, and also accurately estimating where the eye gaze is directed to, within a few degrees of accuracy. The system operates at wavelengths where light has its maximum depth of penetration in biological tissue, and by analyzing the data using deep learning algorithms, we can go beyond what is typically possible with standard methods of near-infrared imaging."

Dr. Tepper adds that the information collected using continuous touchless monitoring is a critical element of the patient's electronic medical record (EMR) and helps with decisions concerning optimal medical treatment.

The investigators conclude, "Our technology, backed by a patent application, paves the way for developing devices with wide-ranging clinical and commercial applications in domains ranging from sleep medicine, through monitoring sedation level and intraoperative awareness in anesthesia, to assessing pain and reactivity in unresponsive patients or in neurology intensive care and trauma wards."

More information: Omer Ben Barak-Dror et al, Touchless short-wave infrared imaging for dynamic rapid pupillometry and gaze estimation in closed eyes, *Communications Medicine* (2024). DOI: 10.1038/s43856-024-00572-1