A light-based wearable to detect sleep apnea

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Sleep apnea, the disorder where normal breathing is disturbed during sleep, can negatively affect someone's mental and physical health. In an Eindhoven MedTech Innovation Center (e/MTIC) research collaboration involving TU/e and the Kempenhaeghe Epilepsy and Sleep Center, Gabriele Papini has developed a way to monitor sleep apnea using a

compact wrist-worn device that is comfortable to wear and can be used for long-term home monitoring. Papini defends his PhD thesis on February 18th at the department of Electrical Engineering.

Leonardo da Vinci once said "A well-spent day brings happy sleep", but the opposite is also true. Sleep is critical for physical and mental rest and recovery, but proper sleep can be disrupted by several disorders, with one of the most common being obstructive sleep apnea (OSA) which affects a billion people worldwide.

"Up to 80% of those with moderate or severe OSA might go undiagnosed, which can have a significant health impact," says Gabriele Papini, PhD researcher in the Biomedical Diagnostics Lab at the department of Electrical Engineering.

OSA blocks the regular flow of air, which can disrupt sleep and deprives the body of an adequate supply of oxygen. "If left untreated, the effects of OSA include daytime sleepiness, fatigue, and cardiovascular issues," notes Papini. "So, well-timed diagnosis is essential."

Turning to wearables

In clinical tests, the gold standards for OSA diagnosis are polysomnography and polygraphic sleep apnea tests, but both require a person to wear sensors overnight to monitor functions like brain activity, heart rate, and muscle activity.

"Signals from the different sensors are combined, and the number of unusual respiratory events per hour of sleep is counted in the combined signal," says Papini. "This is known as the apnea-hypopnea index."

However, the gold standard OSA tools are not suited for screening and for monitoring over multiple nights as the sensors can be uncomfortable

to wear, can affect sleep, and would be impossible for a person to use at home. "My research looked at a way to take measurements in comfortable way that could be used by a patient at home, and that also solves the screening and monitoring issues."

And the key to Papini's solution? Well, it's a method inspired by popular wearables such as smartwatches and fitness trackers.

Getting the green light

"We wanted to design a system that was compact, that didn't need to be operated by a sleep clinician, and that someone could easily use themselves," says Papini.

So, Papini and his colleagues developed a method using a wrist-worn device that looks like a smartwatch or fitness tracker and involves illuminating the skin with green light from LEDs. Part of the light is reflected by the blood in the body, and then detected by a light sensor.

And for the research 500 people, both healthy individuals and those with sleeping disorders such as OSA or insomnia, wore the device while sleeping. More on these experiments in a bit, but what information is contained in the reflected light signal?

"First, the signal contains heartbeat pulses, which can be checked for changes that might be related to OSA," says Papini. "The same signal also contains information on the respiratory system, and this can also be used to diagnose OSA, but before properly analyzing the signal, we needed to improve signal quality."

During sleep, signal noise can result from factors like movement or increased pressure on the watch during sleep. So, Papini calculated an average pulse from the signal, compared every pulse with the average

pulse to find the pulses affected by noise, and then removed them. As normal breathing is affected by OSA, Papini then isolated the respiratory part of the signal by looking at the variations in the pulse amplitudes.

Putting it to the experimental test

With the wrist-worn green light device and a way for getting clean signals in place, the device was then put to the test. However, the signals are quite complex to analyze, so Papini turned to deep learning for a helping hand.

"We used deep learning convolutional models to identify the respiratory events, and then used these to calculate the apnea-hypopnea index (AHI) for a patient," notes Papini.

The deep learning model was first trained using recordings from 250 patients with and without sleeping disorders. Then the trained model was used to check for OSA in signals from another 250 patients. And, the results were quite promising.

"The AHI values calculated using our wrist-worn device were in good agreement with the AHI values calculated with the gold standard approaches. So, it is conceivable for a person to use this device to screen and monitor OSA at home," says Papini.

Future sleep

The promising results have Sebastiaan Overeem, somnologist at Kempenhaeghe and Papini's main supervisor, very optimistic about the future: "Hopefully, this research will lead to new techniques that, in addition to a better diagnosis, can also check on the efficiency of treatments for patients with sleep disorders. And importantly, the device

could be used at home and for prolonged periods of time."

Papini is quick though to point out an important aspect of the wrist-worn device. "Unfortunately, it's not as accurate as the gold standard approaches, particularly those that measure brainwaves, and will never replace the gold standard. But clinicians could ask patients to use the device when they want to monitor OSA for a long time and without the need for lots of cables and sensors."

So, while da Vinci professed the importance of a well-spent day for happy sleep, his fellow Italian Gabriele Papini has created a device to diagnose the cause of unhappy sleep that could help more and more people to experience those well-spent days.

More information: Thesis: research.tue.nl/en/publication … toring-using-cardiov

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