MINDS IN SYNC: EXPLORING THE NEXUS OF HUMANS ON A CHIP AND WEARABLE TECHNOLOGIES ON COGNITIVE MEASURES OF HUMAN PERFORMANCE

Ear Wearable Device (EWD) For Measuring Core Body Temperature, EKG, SpO2 And Other Physiological Signatures.

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Extreme heat exposure during physical exertion causes a rise in body temperature and an increased cardiovascular response, impairing performance. In severe cases, overheating can lead to heat stroke and death. EWD is an instrumented earbud that can measure kinematic and physiological signals such as 3-axis head accelerations, 3-axis rotation rates, head orientations (roll, pitch yaw), head angular accelerations, cerebral oxygen saturation, heart rate, heart rate variability, breathing rate, breathing rate variability, and body temperature. These signals can be used to detect adverse events like hypoxia, hyperventilation, unusual head and neck ergonomics, excessive/ restricted neck motion, thermal stress, excessive vibration, fatigue, acceleration atelectasis, pulmonary distress, anxiety (based on berating rate and heart rate variation and spatial disorientation.

The development of the EWD system was a collaboration between the Naval Surface Warfare Center Indian Head Division (NSWC IHD), Naval Health Research Center (NHRC), and ASU. The U.S. Navy (NSWC-IHD) and ASU filed a patent on the EWD technology in 2022. Using an iPhone App developed by ASU (connected via Bluetooth to EWD is capable of geotagging activity detection and remote monitoring of warfighters at the individual and troop levels.
EWD was extensively tested for functionality, user comfort, and accuracy using a rigorous human-subject testing protocol approved by NHRC's Institutional Review Board (IRB) (NHRC.2020.0017). The data collected from EWD were compared with the gold standard FDA-approved systems and other commercial off-the-shelf (COTS) wearable systems. The team gathered SpO2, heart rate, core body temperature, 3-axis acceleration, respiration rate, and EKG data during testing.

It can be noted that the tympanic membrane may be a suitable site to achieve a reasonable estimate of core body temperature as it is easily accessible, situated close to the primary human thermoregulatory node, the hypothalamus, and it has blood vessels. There are three main issues with measuring tympanic temperature. Environmental factors may impact tympanic temperature, including temperature, wind, and head heating/cooling. It might be challenging to obtain accurate tympanic temperature readings, mainly when doing so continuously in an operational environment. If constantly used, the I.R. sensor may provide inaccurate results due to self-heating and sweat condensation on the lens. However, designing the earpiece so that the tip of the earbud reaches the 2nd bend of the ear canal so that the I.R. sensor can directly see the lower half of the tympanic membrane would help measure the tympanic temperature accurately. To minimize the self-heating, we would adjust the duty cycle of the I.R. sensor so that it can estimate temperature at varying frequencies, 2 Hz to 5 Hz, allowing the sensor to cool down in between measurements. The earpiece must have a vent tube to ensure that sweat condensation will not occlude the sensor's lens.

The algorithm performance can be improved by including activity information (walking, running, jogging, sitting) in the proposed algorithm. It is anticipated that a microclimate cooling system such as a liquid-cooled garment (LCG) controlled in a closed loop with EWD-measured core body temperature would minimize the heat stress events in warfighters.

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