EYELID VIGILANCE DETECTOR SYSTEM

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FIELD OF THE INVENTION

The present invention relates to vigilance detection systems and methods and, more particularly, to a system and method for accurately detecting vigilance loss of a subject at an early stage thereof by monitoring the frequency of small active eyelid movements of the subject.

BACKGROUND OF THE INVENTION

Many safety-related casualties and mishaps are caused by persons falling asleep while performing various tasks. For example, a large number of automobile accidents are caused by persons falling asleep while driving. A need therefor exists for a safety system that accurately monitors the vigilance (alertness) of a person and provides a warning to awaken that person at an early stage of vigilance loss.

The need for such a system has been recognized as numerous attempts have been made at designing an effective vigilance detection and warning system. None of the vigilance detection systems to date, however, accurately detects vigilance loss at a sufficiently early stage thereof to prevent safety-related casualties. The systems also suffer from other less serious drawbacks.

U.S. Pat. Nos. 3,863,243 (Skolnick et al.), 4,144,531 (Anbergen) and 4,953,111 (Yamamoto et al.) disclose prior art vigilance detection systems that employ an optical/electrical circuit for detecting eyelid movement. All of the disclosed systems optically monitor the frequency of complete eyelid closures or blinks; the Skolnick and Yamamoto systems do so directly while the Anbergen system does so indirectly by detecting eyelash movements. The disclosed systems are ineffective at providing a warning signal at an early stage of vigilance loss because the systems provide a warning signal only after a predefined threshold time period without a blink, which typically occurs at a relatively late stage of vigilance loss. In addition, such systems require the subject to wear glasses or goggles to carry the delicate optical circuitry. If the glasses or goggles are not precisely placed on the subject, then faulty operation may result.

Another prior art system includes a light-weight plastic head-piece that is placed on the head of a subject being monitored and provides an audio alarm signal to awaken the subject in response to significant radial head movements from a predefined alert state orientation, such as head nods. The head-piece system also is ineffective at warning the subject at an early stage of vigilance loss because head nods typically occur at a relatively late stage of vigilance loss. The head-piece system suffers from the additional drawback that voluntary radial head movements can falsely trigger the device to provide an alarm signal.

A further prior art system, described in U.S. Pat. No. 4,359,724 (Zimmerman), monitors the frequency of significant eyelid movements (i.e., blinks) of a subject. The Zimmerman system includes EMG electrodes that are placed on the eyelids of a subject and produce an electric signal in response to each significant eyelid movement. Analog circuitry, electrically connected to the sensors, includes a timer that is reset each time an electric signal is received. If the timer is not reset within a certain time period, then an audio alarm signal is provided to awaken the subject. Like the prior art optical systems, the Zimmerman system similarly monitors the frequency of blinks and therefore also is incapable of alarming a subject at an early stage of vigilance loss. The Zimmerman system additionally suffers from the drawbacks that EMG sensors are bulky and cumbersome and require precise placement for accurate operation.

Accordingly, a general object of the present invention is to provide a simple yet accurate system and method for monitoring the vigilance of a subject that detects vigilance loss at an early stage thereof.

SUMMARY OF THE INVENTION

Eyelid movements generally fall into three categories: (1) "large active" or significant eyelid movements such as blinks; (2) "small active" eyelid movements which are substantially less significant movements than large active eyelid movements; and (3) "passive" eyelid movements, which are less significant movements than small active movements and which are caused by movements of the eyeball underneath the eyelid. Small active eyelid movements are caused by involuntary twitches of the eyelid muscle when the muscle maintains the eyelid open in response to neuronal signals received from the brain.

It is known that vigilance is related to the frequency of large active eyelid movements. Applicants have discovered through clinical studies that vigilance also is related to the frequency of small active eyelid movements. It additionally has been determined that a decrease in the frequency of small active eyelid movements occurs at an earlier stage of vigilance loss than does a decrease in the frequency of large active eyelid movements.

The drawbacks of the prior art are overcome by a vigilance monitoring system of the present invention that provides an alarm signal to a subject at an early stage of vigilance loss. The system includes a sensor, preferably a piezoelectric sensor, that is attached to the eyelid of a subject and that produces an electric signal in response to each eyelid movement. The strength of the signal depends on the magnitude of the eyelid movement. A processor, electrically coupled to the sensor, monitors the frequency of electric signals received having a signal strength above a threshold level corresponding to a small active eyelid movement. The processor produces an output signal if the frequency of received electric signals having the signal strength above the threshold level is less than a predetermined frequency.

In the preferred embodiment of the present invention, the output signal includes an audio alarm signal provided to an output loudspeaker.

The processor preferably includes a signal recording circuit and a programmable microprocessor, wherein the signal recording circuit is electrically connected between the sensor and the microprocessor. The signal recording circuit preferably includes an analog peak detection circuit, a comparator, and a short term event buffer. The analog peak detection circuit is coupled to the sensor and stores the highest strength electric signal received during each predetermined time period. The comparator is coupled to the peak detection circuit and compares the highest strength electric signal to a threshold level signal during each predetermined time period. The short term event buffer is coupled to the comparator and has a number of address locations, each address location corresponding to a separate time period and