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Operator Drowsiness Test

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Abstract:

This publication details a quantifiable and objective operator drowsiness test. The test takes between 30 seconds to two (2) minutes to be administered. Any smartphone that has a front-facing camera and the supporting software can run the newly-developed and self-administrable test. It leverages years in sleep deprivation research that have found objective correlations between drowsiness (or alertness) and physical and behavioral parameters, such as: gazing, facial features, pupil size, blink rate, blink duration, breathing, pulse, head movements, face skin-tone, speech pattern, and vocal sound. In addition, the mass use of smartphones with rear-facing and front-facing cameras gives researchers the opportunity to deploy this new operator drowsiness test to a wide audience.

Keywords: operator drowsiness, machine learning, psychomotor vigilance test (PVT), gaze, neural network, dense neural network, artificial intelligence (AI)

Background:

According to the Centers for Disease Control and Prevention (CDC), drowsy driving is a major problem in the United States. Drowsy driving is a combination of driving and sleepiness or fatigue. It occurs when a driver has not slept enough, but it can also occur due to untreated sleep disorders, medications, shift-work, or consumption of alcohol or other legal or illegal substances. Drowsiness inhibits a driver's ability to pay attention to the road, slows reaction time, and affects a driver's ability to make good decisions. In addition, the National Highway Traffic Safety Administration estimates that drowsy driving was responsible for 72,000 crashes, 44,000 injuries, and 800 deaths in 2013. Nevertheless, these numbers are underestimated; up to 6,000 fatal crashes each year may be caused by drowsy drivers. Among other factors, America's sleep deprivation contributes to this disturbing phenomenon. Fig.1 demonstrates how sleep deprivation manifests itself while driving.

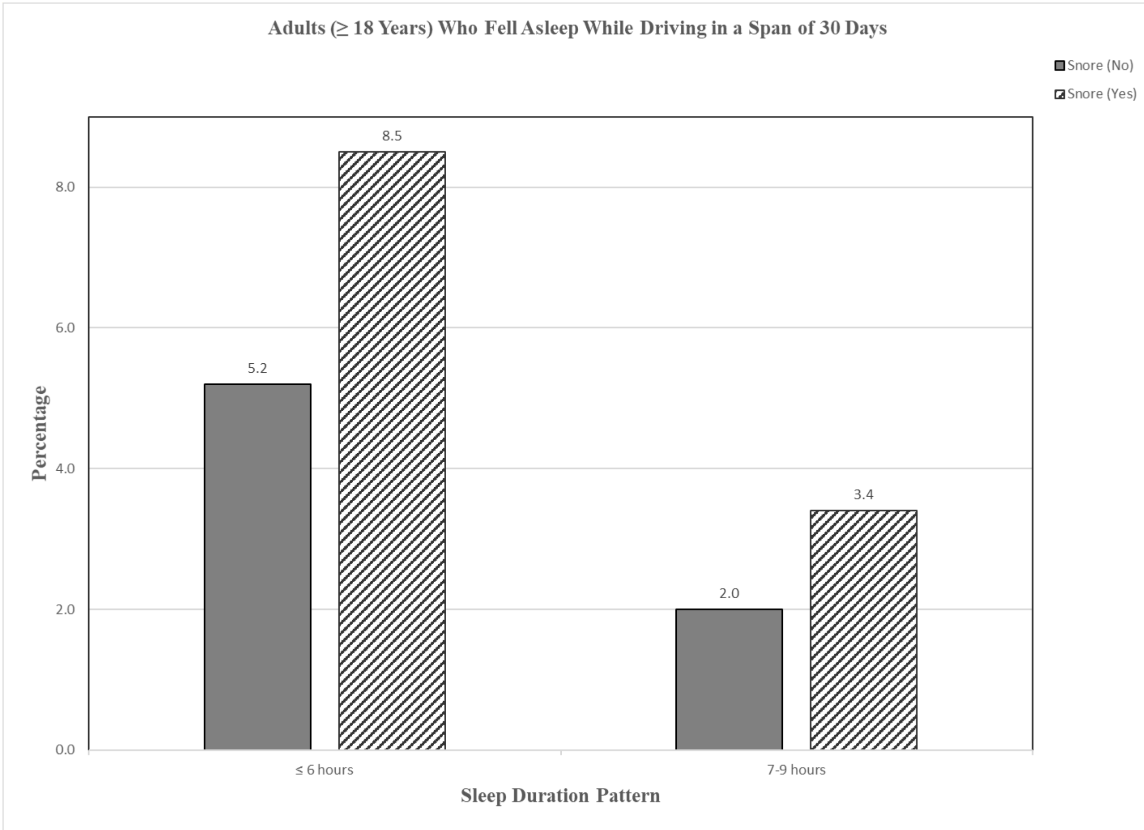

Fig.1

The Behavioral Risk Factor Surveillance System surveyed 150,000 adults in 19 states and the District of Colombia; the responses are shown in Fig. 1. Sleeping six (6) hours or fewer per day or snoring increases a person's likelihood of falling asleep while driving.

Several states have attempted to adopt laws to make drowsy or fatigue driving a punishable offense, but due to the subjectivity of who is considered a drowsy driver, this course of action has produced mixed results. Unlike the various objective tests to measure a driver's level of intoxication, law enforcement and the courts do not possess a well-established drowsy driving test, which makes punishing drowsy driving challenging.

Drowsy driving is just one operator drowsiness related problem. Operator drowsiness detrimentally affects many activities in an industrialized society. To this end, researchers have created self-administered tests to measure a person's alertness; the psychomotor vigilance test (PVT) is such a test. The PVT is a tool used to measure a person's behavioral alertness. It is a visual test that involves measuring the speed at which a person reacts to visual stimuli (e.g., a red dot against a black background). The PVT is becoming a valuable tool in the sleep field as it is a good measure of behavioral alertness in relation to sleep loss (sleep deprivation) or circadian rhythm misalignment. For example, the International Space Station crew uses the PVT to monitor the daily effects of fatigue on the crew's performance.

Nevertheless, the standard PVT takes 10 minutes to be administered—therefore, it is not suitable for a wide audience. Furthermore, the PVT uses only reaction time to test alertness, and does not assess other physical and behavioral parameters that change with drowsiness, such as: gazing, facial features, pupil size, blink rate, blink duration, breathing, pulse, head movements, face skin-tone, speech pattern, and vocal sound.

Description:

Technological advancements create the possibility to elevate operator drowsiness tests beyond what is currently measured with the PVT. In addition, the mass use of smartphones with rear- and front-facing cameras gives researchers the opportunity to deploy a new operator drowsiness test to a wide audience. Although the PVT is a valuable tool in measuring a person's behavioral alertness, it only uses reaction time, and ignores other drowsiness related symptoms. In addition, the standard PVT takes 10 minutes to be administered. This long administration time is one reason why the PVT is not used by many professions—let alone everyday drivers.

Drowsy driving and other operator drowsiness errors were the impetuses for the creation of this new technology. Sleep deprivation researchers have established objective links between drowsiness (or fatigue) and the following physical and behavioral parameters: gazing, visual tracking, facial features, pupil size, blink rate, blink duration, breathing, pulse, head movements, face skin-tone, speech pattern, and vocal sound. Below is a high-level overview of the correlations between drowsiness and the following physical and behavioral parameters:

Gazing—There is a positive correlation between a person's alertness and a person's ability to gaze (or fixate) on an object (e.g., a red dot, a target, and a pattern).

Visual tracking—There is a positive correlation between a person's alertness and a person's ability to track flashing objects on a screen.

Facial features—A person's drowsiness manifests itself with drooping eyelids (extreme drowsiness), yawning, slight opening of the lips, mouth movement, and changes in wrinkles between eyebrows, nasolabial folds, and corners of the mouth.

Pupil size—Drowsiness lowers pupil stability; that is, a well-rested person can maintain an enlarged pupil longer than a drowsy person can. In addition, there is a positive correlation between alertness and the pupil size; that is, alert individuals have enlarged pupils.

Blink rate—There is a positive correlation between a person's alertness and a person's blink rate; that is, drowsy individuals blink slower than well-rested individuals.

Blink duration—There is a positive correlation between drowsiness and the duration of a blink; that is, the blink duration increases with an increase in drowsiness (or a decrease in alertness).

Breathing—Breathing rate slows down with a decrease in alertness. Furthermore, the breathing pattern becomes more regular with a decrease in alertness.

Pulse—There is a positive correlation between a person's alertness and a person's pulse rate (or heart rate); that is, the heart rate is lower in drowsy individuals compared to well-rested individuals.

Head movements—There is an increase in velocity and the number of extreme head movements (e.g., bobbing) in sleep deprived individuals.

Face skin-tone—Skin temperature rises in sleep deprived individuals. Therefore, the face skin-tone will appear with a deeper reddish hue.

Speech pattern—A sleep deprived individual speaks slower than a well-rested individual. In addition, slurred speech is a good indication of intoxication.

Vocal sound—There is a positive correlation between hoarseness and drowsiness.

As one can see, the standard PTV ignores many physical and behavioral parameters that are associated with drowsiness. Furthermore, these relationships are quantifiable beyond a binary classification (1 or 0; yes or no; alert or drowsy), therefore, the combination of these tests gives granularity on a person's alertness level.

Any smartphone with a camera (preferably a front-facing camera so audio and video may be used during the test) and the supporting software can run the newly-developed and self-administrable test. Unlike the PVT, the new test can be administered between 30 seconds to two (2) minutes. The exact time depends on the type of operation the individual is gearing up to perform—not all operations require the same alertness level. The test involves the operator looking at the screen display and performing a set of simple tasks. For example, the operator will be asked to gaze (or fixate) on an object in a short video. The front-facing camera will monitor the individual's eye movement. The software will generate a score based on the operator's ability to gaze and determine the alertness level.

Machine learning, via several neural networks, enables the training of the software. Fig. 2 illustrates how the software is trained regarding each physical and behavioral parameter that is correlated with drowsiness (or alertness).

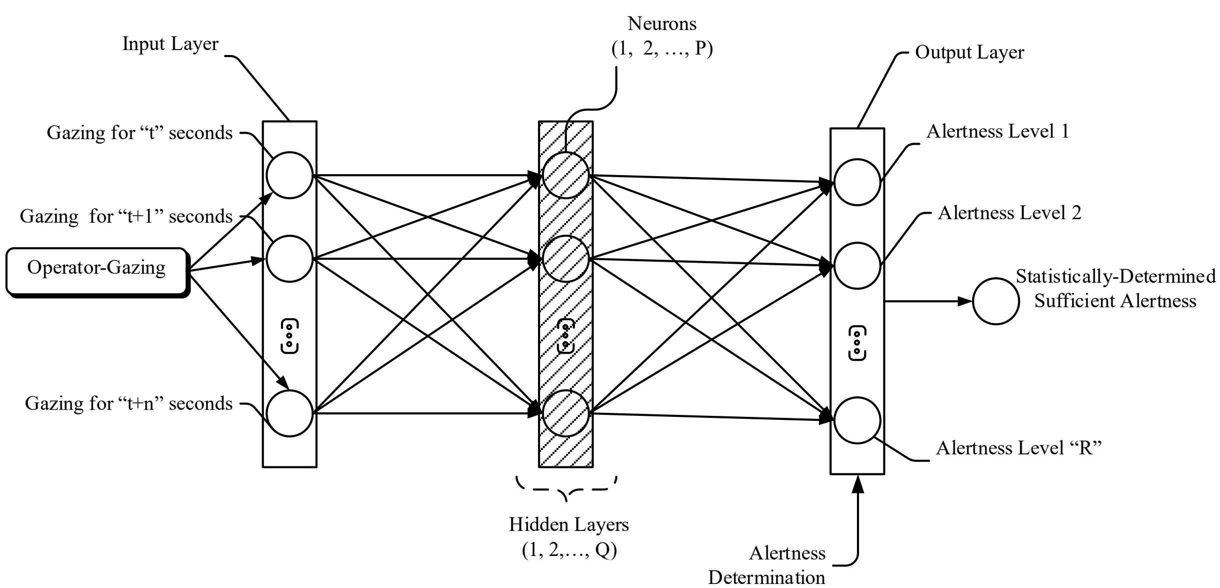

Fig. 2

The neural network in Fig. 2 illustrates an input layer, several hidden layers, and an output layer. The input layer includes "n" number of timed-gazing from several end users. There are "Q" number of hidden layers, with up to "P" number of neurons in each layer. There can be a different quantity of neurons in each hidden layer. The output layer includes "R" number of bins which represent different alertness levels. As one can see, this test is objective and quantifiable beyond a binary classification (e.g., alert or drowsy).

Like the neural network illustrated in Fig. 2, eleven (11) other neural networks evaluate a person's alertness via visual tracking, facial features, pupil size, blink rate, blink duration, breathing, pulse, head movements, face skin-tone, speech pattern, and vocal sound. To use the operator's voice to determine the level of alertness, the software requires the operator to read out loud a phrase displayed on the screen or describe an image displayed on the screen.

The newly-developed test individually trains each neural network in order to increase its accuracy, and the outcome of these neural networks are integrated into a final dense neural network as shown in Fig. 3.

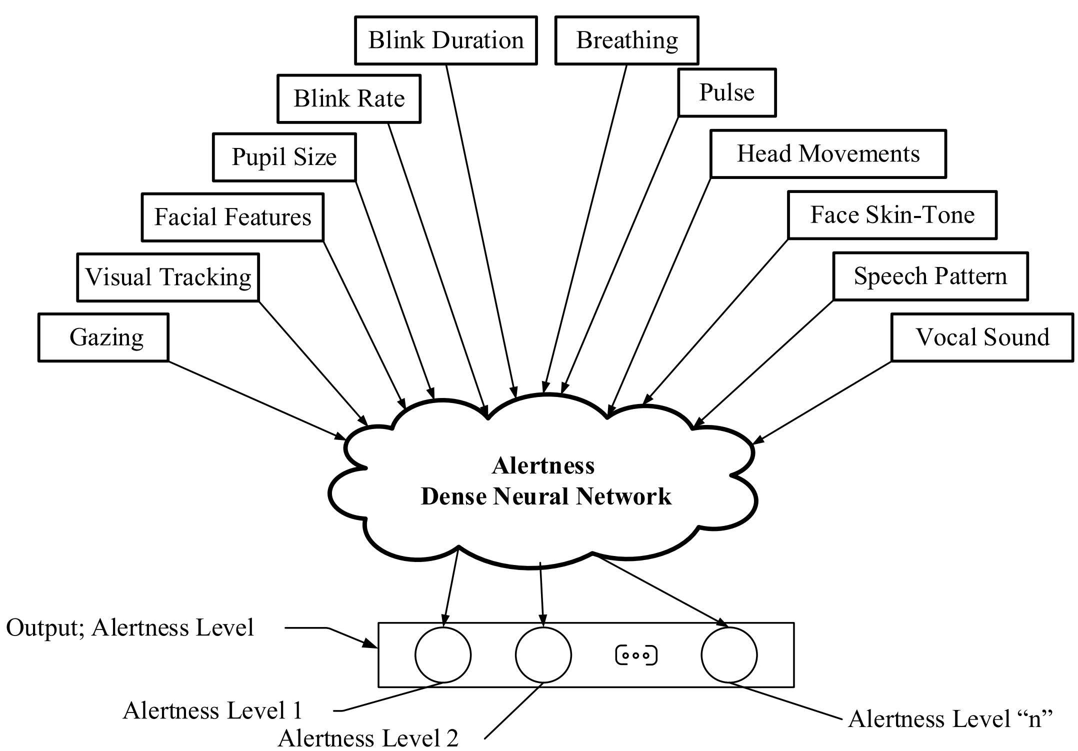

Fig. 3

Fig. 3 demonstrates how the outputs of the neural networks, which evaluate each physical and behavioral parameter correlated to drowsiness (or alertness) serve, as the input of a final dense neural network. One can imagine how difficult is to fake alertness when multiple physical and behavioral parameters are being evaluated. In addition, the software engages the end user with new and random tasks to eliminate the possibility of the end user to become familiar with the operator drowsiness test. Furthermore, if one of the behavioral or physical parameters fails to certainly and objectively determine the end user's alertness level, the other parameters will compensate for such lack of uncertainty and objectivity and add confidence to the final answer: is the end user alert? If so, what is the alertness level?

This operator drowsiness test, combined with facial recognition software, may be used in many professions, industries, and daily activities, such as: driving, healthcare, financial trading, factories, insurance companies, law enforcement, courts, military, space exploration, sports, and individually self-imposed testing.

Operator drowsiness causes the loss of many lives, lowers productivity, and costs America billions of dollars annually. This newly-developed, self-administrable, objective, and quantifiable operator drowsiness test could reverse this alarming trend.