WG 8 (Aerospace Medicine)

Voice Biomarkers of Fatigue

Noga Hellmann.
Medical Corps, IDF.

Fatigue impairs various cognitive functions, but currently, no objective, validated measure exists to quantify it. In the last two decades, studies have used speech analysis to detect and monitor medical, physiological, and mental conditions. The objective of this study is to develop an algorithm based on acoustic measurements to evaluate the fatigue level of aircrew under sleep deprivation (SD) conditions. This study included recordings of 40 aircrews and UAV operators, each recorded in four different SD stages: slight fatigue, severe fatigue, accumulated fatigue, and recovery. The recording protocol included various speech signals, such as syllables, counting, reading, speech under cognitive load, and free speech. A qualitative perceptual analysis was conducted by a speech therapist to compare and interpret the results. The analysis involved computing the distance between acoustic features in the states of alertness and slight fatigue, as well as between alertness and maximal fatigue. Both speaker-dependent (comparison of recordings from the same subject) and speaker-independent (comparison of recordings from all participants) analyses were performed. In the speaker-dependent analysis, some features showed a greater distance between alertness and maximal fatigue compared to the distance between alertness and slight fatigue. These features included all d-LPC derivations (with 70-80% identification), PARCOR (77%), LPC (76%), pitch (F0) (76%), and MFCC (75%). The speaker-independent analysis did not yield significant results, and a larger cohort is required for further analysis. This study demonstrated a high correlation between fatigue and vocal characteristics. This connection could be measured by analyzing the distance between acoustic features in the state of fatigue and those in the state of alertness for each individual. These results suggest the potential for developing a user-dependent fatigue sensor.

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Extraction of Brain Error-Monitoring Metrics from Joystick Movement to Detect Aircrew Fatigue

Eldad Hochman.
CorrActions Ltd.

The most effective method for fatigue monitoring is EEG, but its use is limited to laboratory or clinical settings. We identified that EEG components related to error monitoring influence corrective sub-movements—subtle micro-motions triggered by error detection—offering a novel fatigue assessment approach. We hypothesized that changes in these sub-movements reflect fatigue levels.

Our model was based on a two-hour driving simulator, where fatigue levels were determined using EEG, KSS ratings (driver and external evaluator), and driving performance. Fatigue level was determined when the driver's self-reported KSS matched an identical indication from at least one other measure. AI analysis identified sub-movement features distinguishing KSS threshold of ≥8 indicating unfitness for activity.

The Israeli Air Force validated the model in two phases. In a Flight simulator study (52 cadet pilots), it detected KSS ≥8 with 79% true alerts and 3% false alerts (all at KSS 7) and identified KSS ≥8 flight patterns with 82% true alerts and 8% false alerts. In UAV operations, it matched instructor evaluations for KSS ≥8 with 78% true alerts and 1% false alerts. The model, initially designed for steering analysis, was minimally adapted for the Air Force test. With dedicated training, it can achieve rapid detection (about 1 min) and very high accuracy, allowing assessment of flight crew fatigue before or during operations.