WP8 USE CASE 3 EVALUATION:
PERCLOS-based Operator Fatigue Detection

HOLISTIC HUMAN FACTORS AND SYSTEM DESIGN
OF ADAPTIVE COOPERATIVE HUMAN-MACHINE SYSTEMS

Motivation

The adaptive, cooperative human-machine-system (*AdCoS*) built by Airbus Defence and Space is able to identify drowsy operators and to encourage them to take countermeasures. The identification is based on a fatigue monitoring system (*FMS*) consisting of multiple optical sensors. If the operator is present and his face is directed towards the screen, an eye-tracker (Fig. 1) will constantly observe the pupil. When the operator's eyes are perceived as closed for longer than a predetermined proportion of the time ("Percentage of eye closure" – *PERCLOS*), the AdCoS will signal to the operator that he/she should take action.

Fig. 1: Tobii x3-20 Remote Eye-Tracker

The objective of this study was to test the reliability and construct validity of the FMS. Over a period of two weeks, an observational study including 15 participants was conducted at the Human Factors Lab (Fig. 2) of the Airbus Defence and Space site in Immenstaad, Germany. Fatigue was induced by collecting data in a dark and warm test environment during the early morning and the mid-afternoon dip.

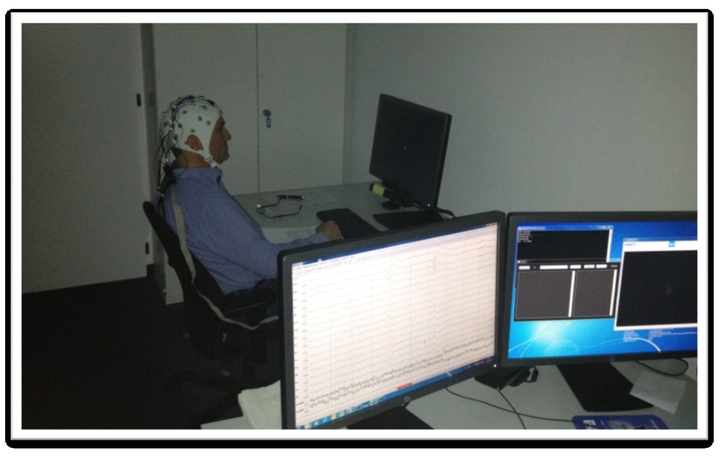

Fig. 2: Experimental setup

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Evaluation

Dependent Variables

Changes in subjective feelings of fatigue were assessed with the Karolinska Sleepiness Scale (KSS, Fig. 3). PERCLOS data were compared to electroencephalography (EEG) measures of fatigue. Electrodes were placed on frontal and posterior parts of the scalp (Fig. 4). Fatigue was scored by means of increasing posterior alpha and theta (slow wave) compared to decreasing overall beta (fast wave) activity $\left(\frac{\propto +\theta}{\beta}\right)$.

1	Extremely alert
2	Very alert
3	Alert
4	Rather alert
5	Neither alert nor sleepy
6	Some signs of sleepiness
7	Sleepy, but no effort to keep awake
8	Sleepy, some effort to keep awake
9	Very sleepy, great effort to keep awake, fighting sleep

Fig. 3: Karolinska Sleepiness Scale

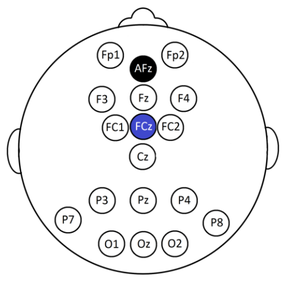

Fig. 4: EEG-Electrode locations (10-20 system

Design

While changes in their physiological and subjective levels of fatigue were monitored, participants performed a continuous performance task (Fig. 5) over the duration of one hour. Data were compared by within-subject Pearson correlations, based on which a general correlation coefficient across subjects (*r*) was computed.

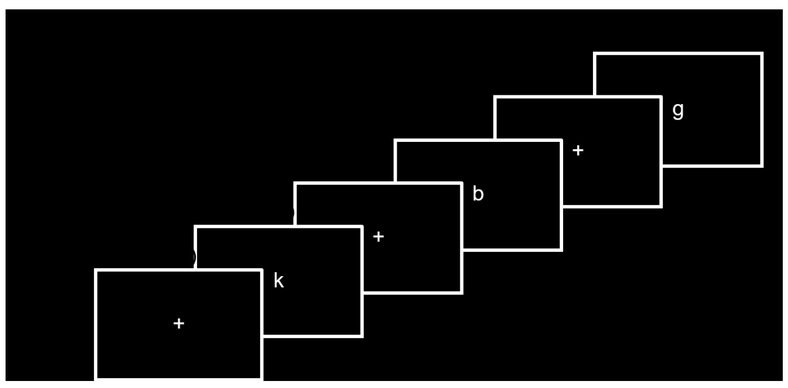

Fig. 5: Continuous Performance Task

Results

The KSS data show that fatigue was successfully induced ($t(12)=4.91$, $p<0.01$). However, only two participants stated they had experienced microsleep and only one was observed not engaging in the performance **task** for longer than 5 s with eyes closed. EEG data of fatigue increased slowly but steadily for all participants while PERCLOS reached his maximum after two thirds of the study and then decreased slowly (Fig. 6).

The scores of PERCLOS and EEG assessments of fatigue did not correlate significantly ($r(11)=0.21$, $p=0.59$; Fig. 7). The eye tracker's opaque algorithms could not be adjusted to the dark but stable lab conditions. Also, in spite of participants feeling sleepy, fatigue levels might still have been too low to cause critical and well-observable drops in wakefulness and performance.

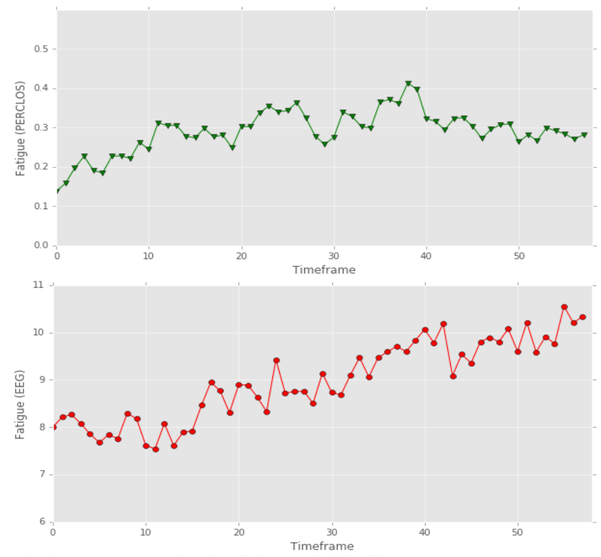

Fig. 6: Fatigue (PERCLOS and EEG) over time

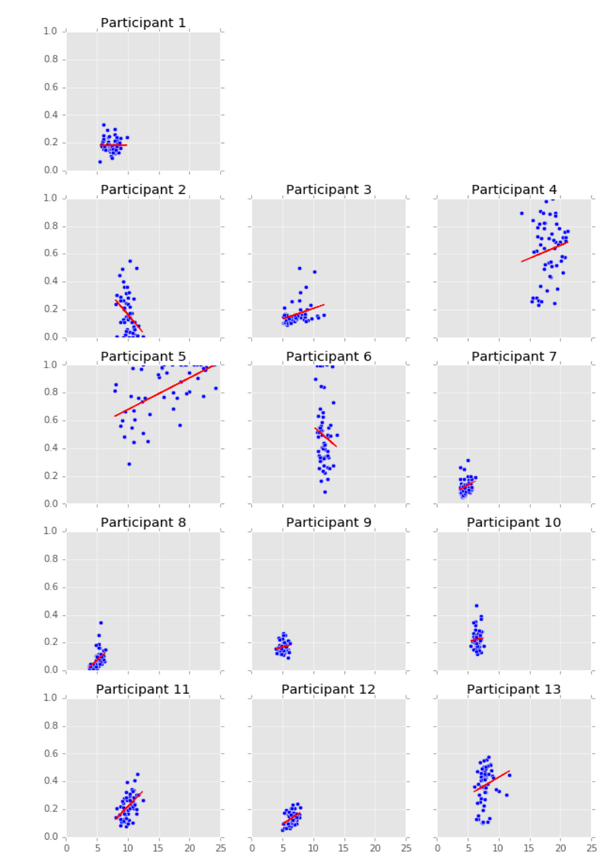

Fig. 7: Correlations per participant (X: EEG, Y: PERCLOS)

Conclusion

The PERCLOS-based FMS has been shown to be sensitive to fatigue. What level of fatigue is critical depends on the context: While most commercially available FMS are designed for tasks where very early levels of fatigue can have severe effects (e.g., driving), higher thresholds might better fit operators' needs in border security control room settings. Based on the findings, design recommendations such as hardware revision with respect to eye tracking and exclusion of interfering (infrared) lighting sources are given.

Consortium

Acknowledgments

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