The LNQ25 and ELN PVT metrics exhibit a good sensitivity to sleep deprivation and are independent from the subject

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Objectives

We analyze and compare the sensitivity to sleep deprivation and the subject dependent variability of the PVT metrics performance, with a special emphasis on the time interval sizes.

Introduction & Context

- Performance of people undergoing critical tasks (like driving) are impaired by the lowering of their vigilance level, due to sleep deprivation.
- Automatic systems compute an alertness level and detect drowsiness. Their assessment proceed by comparison with validated indices.
- We consider the 10min standardized PVT (Psychomotor Vigilance Test) as a validated index

PVT metrics computed on short time intervals

- Some metrics computed with all the reaction times (RT) of a 10min PVT are good indicators of sleep deprived states.
- But, the assessment of "real-time" performances requires indices to be computed on much shorter time intervals (from 20sec to 2min).

Classification of PVT metrics into SDP or Non-SDP

- PVT metrics measure the performance of a person and we assume it to be related in some ways to the alertness level of this person.
- We separate the range of possible metrics values into two classes: Sleep Deprived state (SDP) and not in a Sleep Deprived state (Non-SDP).

Materials & Methods

- 22 volunteers (11 males, 11 females, mean 22.2y., range 19-34 years)
- 28h sleep deprivation standard PVT protocol with six PVT sessions. [1]
- The first two PVT are in Non-SDP condition (9h30, 10h30 Day 1) while the other PVT are in SDP condition (2h30, 3h30, 10h30, 11h30 Day 2).
- The subjects had a normal sleep-wake cycle during the week prior the experiment (no sleep deprivation, jet-lag or shift work and no medication).

PVT metrics

We compute the usual PVT metrics; ***meanRT***, ***meanRS*** (Reaction Speed) and ***LN500*** (500ms lapses number). We also compute the ***LNQ25*** (adaptive lapses number computed with a subject dependent threshold) and the ***ELN*** (Expected Lapse Number, computed from a subject dependent estimation of the lapse probability). [2]

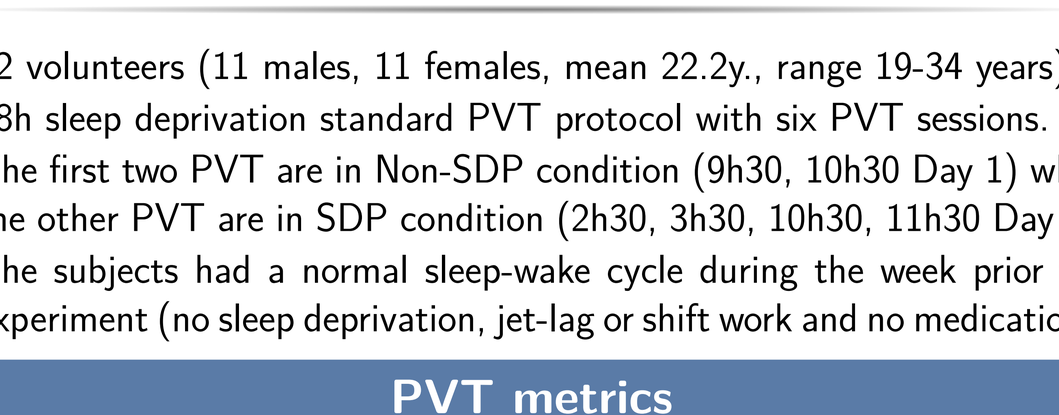

Figure 1 : Computation of ***LNQ25*** metric.

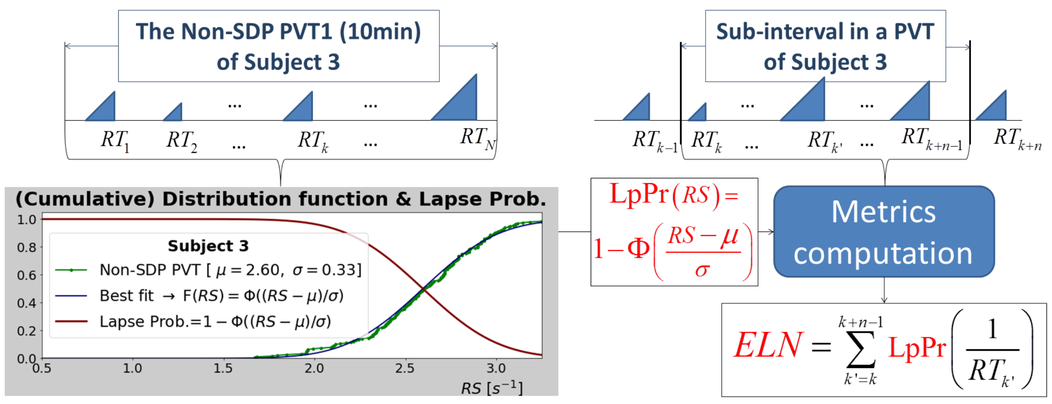

Figure 2 : Computation of ***ELN*** metric.

Results

Effect Size

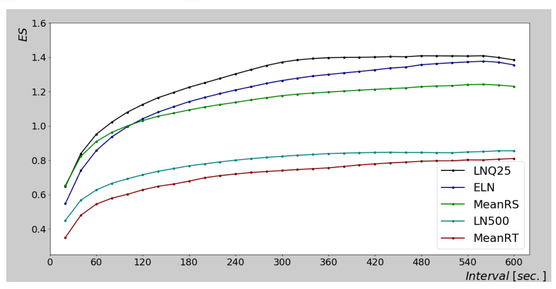

Figure 3 : Effect Size of PVT metrics differences.

For a given subject, the effect of sleep deprivation is measured by the difference of PVT metrics in the SDP and Non-SDP states. The ratio of the mean by the standard deviation (for all subjects) of these differences is the "Effect Size" (ES) of sleep deprivation for the PVT metrics. [3]

Subject-independent SDP/Non-SDP classification

We consider the two distributions of the values of one PVT metric; when people are in a SDP state or not. These distributions, when computed for one subject, are often well separated by a subject-dependent threshold. The extend to which they are also clearly separated by a subject-independent threshold when computed for all subjects is one way to assess a form of independance from the subject for the PVT metrics.

Evaluation of the SDP/Non-SDP classification

We use a subject-independent threshold to class the PVT metric values (SDP/Non-SDP):

- PVT metrics values in SDP states upper (resp. lower) than the threshold are True Positive (TP) (resp. False Negative (FN)).
- PVT metrics values in Non-SDP states lower (resp. upper) than the threshold are True Negative (TN) (resp. False Positive (FP)).

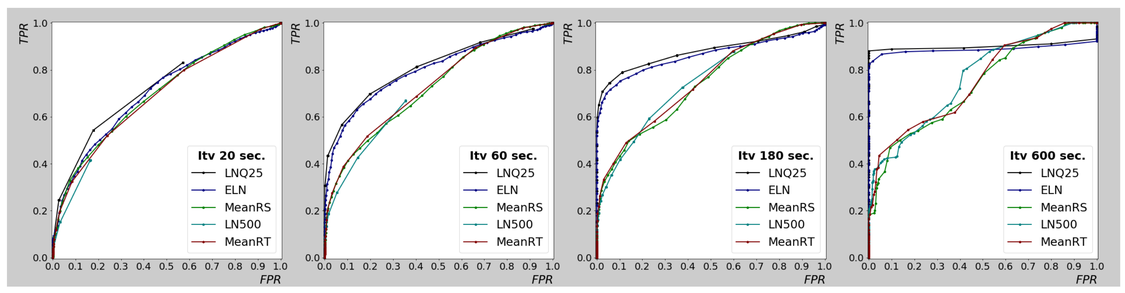

Figure 4 : ROC Space for PVT Metrics.

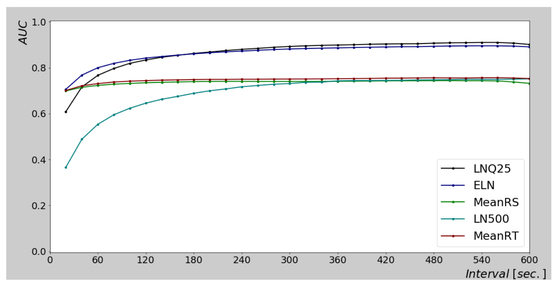

Figure 5 : Area Under the ROC Curve.

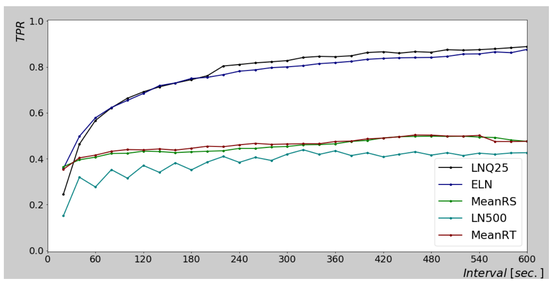

Figure 6 : TPR (with FPR=0.1).

Conclusions

We observed that the ***LNQ25*** and ***ELN*** metrics enable a good classification of the SDP condition for time intervals greater than or equal to 3min, independently of the subject. And, these metrics provide also a good sensitivity to sleep deprivation. They outperform the usual metrics for both criteria. For time intervals below 3min, the performances first degrade progressively and then more rapidly below 1min.

References

[1] C. François, T. Hoyoux, T. Langohr, J. Wertz, and J. Verly. Tests of a new drowsiness characterization and monitoring system based on ocular parameters. *International Journal of Environmental Research and Public Health*, 13(2):174, 2016.

[2] P. Latour and M. Van Droogenbroeck. New PVT metrics with improved sensitivity to sleep loss: Analysis from short to long time intervals. In *International Conference on Managing Fatigue*, San Diego, California, USA, March 2017.

[3] M. Basner and D. Dinges. Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. *Sleep*, 34(5):581–591, 2011.

Acknowledgements

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