Tenth International Conference on Managing Fatigue: Final Abstract

New PVT Metrics with an Improved Sensitivity to Sleep Deprivation: Analysis from Short to Long Time Intervals

LATOUR Philippe, University of Liège, philippe.latour@ulg.ac.be, corresponding author

VAN DROOGENBROECK Marc, University of Liège, m.vandroogenbroeck@ulg.ac.be

Problem

Sleep deprivation progressively degrades the performance of people on attentional tasks (like driving, security monitoring, etc.) up to finally impairing them completely. This degradation/impairment can be measured by some metrics computed from the reaction times (RT) obtained during a Psychomotor Vigilance Test (PVT) of a 10min duration [Dinges1985, Basner2011a].

Today, automatic systems monitor people in real time and try to detect their 'instantaneous' sleepiness level [François2016]. Such systems require, for their validation, some reference sleepiness metrics based on very short time interval duration (from 20s to 2 min).

Despite the fact that some authors [Basner2011b] reduce the global duration of PVT to 3min, there is an obvious need to study the sensitivity of PVT metrics computed over shorter time intervals extracted along a 10min PVT.

Method

We use a standard PVT protocol, approved by the ethics committee of the University of Liège.

22 volunteers (11 males, 11 females, mean 22.2y., range 19-34 years) follow the uninterrupted 28h sleep deprivation protocol described hereafter (and depicted in the figure 1):

1. The subjects arrive at the laboratory at 8h30, day 1.
2. They pass two PVTs (1 and 2) at 9h30 and 10h30, day 1.
3. Then they are free to go home or at work, but they are wearing an actigraph to check that they will not sleep during the day.
4. They come back to the laboratory at 20h30, day1.
5. They pass two PVTs (3 and 4) at 2h30 and 3h30, during the night.
6. They pass two PVTs (5 and 6) at 10h30 and 11h30, day 2.

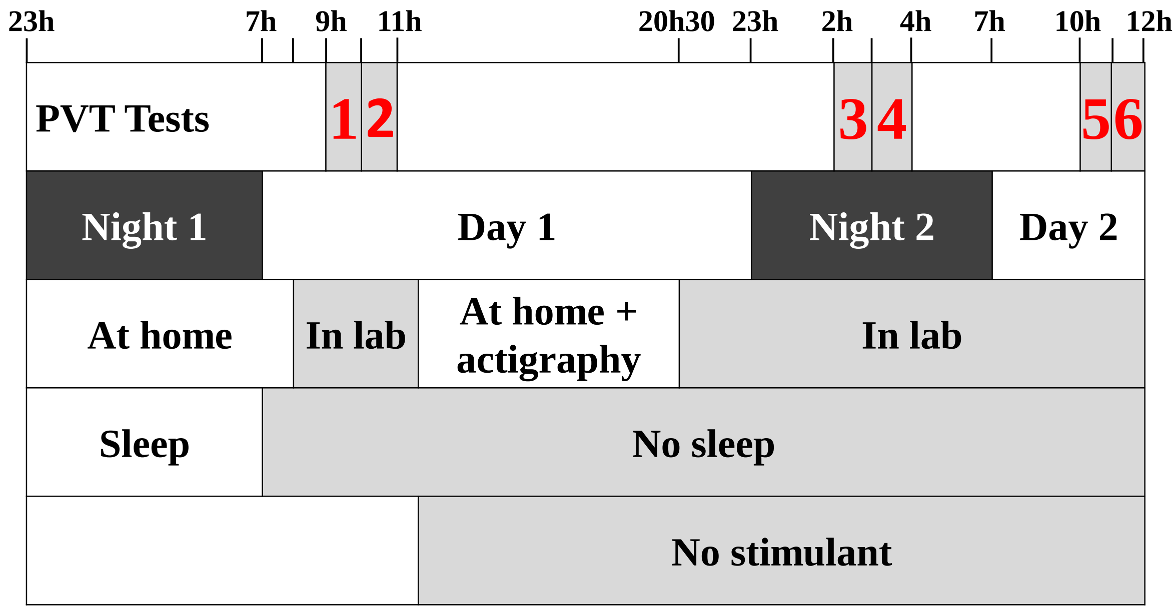

Figure 1 : *Data acquisition protocol (adapted, with permission, from [François2016])*

We have compared the sensitivity to sleep deprivation of five PVT metrics. The first three metrics, given hereafter, are well known in the literature [Basner2011a]:

1. The mean RT (*meanRT*),
2. The mean Reaction Speed (*meanRS*); it is the mean of the inverse of the RT, and
3. The number of lapses (*LN500*), defined as RT greater than 500ms.

To differentiate between Sleep Deprived (SDP) and Non Sleep Deprived (Non-SDP) states, we need to set a threshold for these metrics. But, these thresholds are not absolute and depend greatly on the people (subject).

We present two new metrics; designed to be independent of the subject and sensitive to sleep deprivation. First, we fit the central part of the RS distribution of the Non-SDP PVT to a Gaussian model, and then define the two metrics as follows:

4. The number of RS smaller than the first quartile (25%) of the fitted model, called Q25 Lapse Number (*LNQ25*).
5. The expected value of the lapse number, called the Expected Lapses Number (*ELN*). The lapse probability for a given RS is provided by the value of the Gaussian model at this RS. The sum of these probabilities, computed on all the RS in a time interval, is an estimator of the number of lapses in this interval.

Results

We assess and compare the sensitivity to sleep deprivation of the PVT metrics by computing and analyzing their effect sizes following a procedure similar to, but adapted from the one described in [Basner2011a].

Effects Sizes (ES) are the mean value of the difference between metrics computed in SDP and Non-SDP conditions divided by their standard deviation. A greater ES thus denotes a higher sensitivity.

We display the evolution of the ES for all metrics as a function of the interval duration on which they are computed. Figure 2 depicts the averaged ES between all SDP PVTs and their corresponding Non-SDP PVTs for the 5 metrics.

The 95% confidence intervals (computed by bootstrapping) and the bootstrap means are included in the figure for each ES in order to asses their statistical significance.

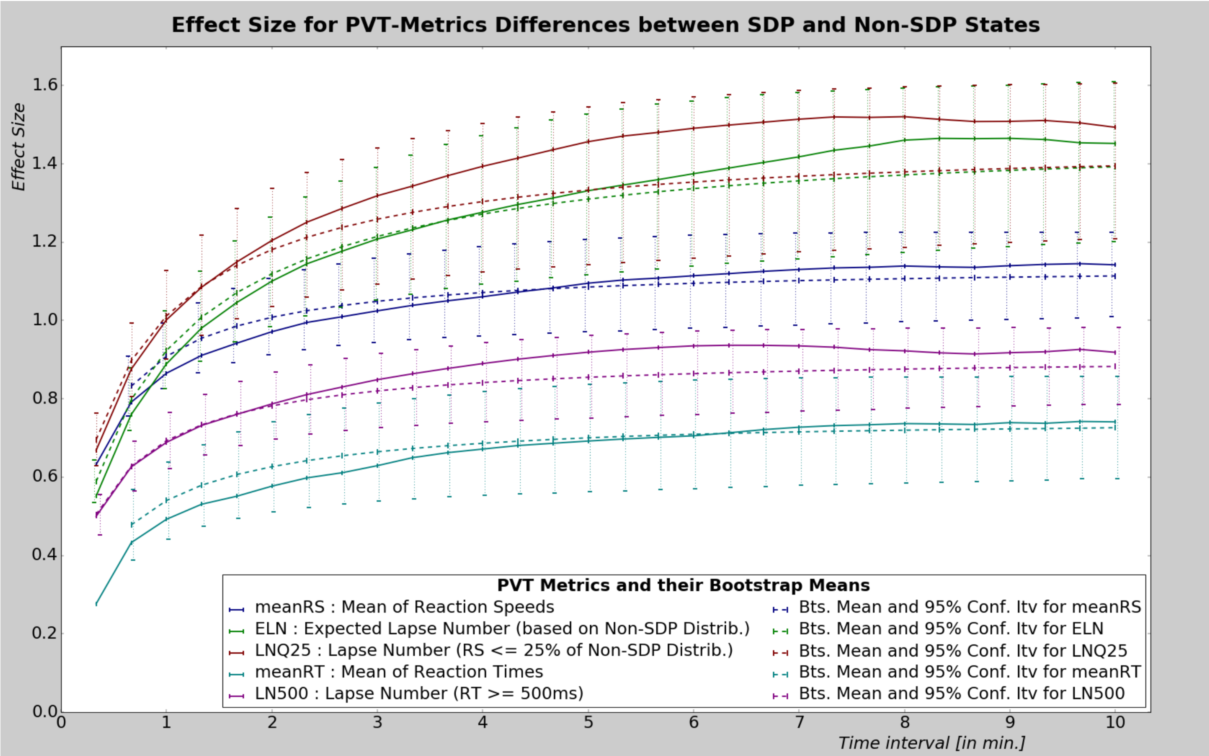

Figure 2 : *Comparison of the Effect Size for the differences of PVT metrics. The figure also depicts their bootstrap mean and the 95% confidence intervals*

Discussion

We observe absolute ES values that are lower than those of [Basner2011a]. The possible reasons are:

1. Our protocol slightly differs and might lower the average sleepiness in our population.
2. We do not investigate the possible temporal correlation between metric values.
3. We use less PVTs; 6 instead of 17 (2 instead of 7 in non-SDP, and 4 instead of 10 in SDP).

However, in terms of the relative values on our data, we observe that the *meanRS*, *LNQ25* and *ELN* metrics are the most sensitive metrics to sleep deprivation.

The new metrics appear to perform well compared to the other metrics. When we consider them on time interval duration greater than 3 min, they clearly outperform the now standard *meanRS*.

On our data, the ES 95% confidence interval of *LNQ25* and *ELN* are greater than 1.0 after 2 minutes. In comparison, even after 10 minutes, the ES 95% confidence interval of the *meanRS* still contains 1.0. In addition, the bootstrap mean of *LNQ25* is greater than 1.0 after 1 minute.

So, on very short time interval duration (1 or 2 minutes), the two new metrics seem also to perform better than the *meanRS*, although the covering of the confidence intervals asks us to remain cautious before drawing definitive conclusions.

A drawback of our new metrics compared to the *meanRS* is that a reference distribution of the RS is necessary to compute them.

Summary

We address the problem of the detection of sleepiness based on PVT metrics computed on a range of time intervals extracted at any position of the 10min test. ‘Short time’ metrics could be very helpful as a reference for automatic sleepiness detection systems.

We introduce two new metrics (*LNQ25* and *ELN*) based on a Gaussian model of Non-SDP distributions of the RS. These metrics appear to perform well for interval durations larger than 2 minutes extracted from 10min PVT; they even outperform the mean RS.

These preliminary results still require a confirmation based on more data.

In conclusion, even if for very short time intervals no metrics perform well enough, *LNQ25* and *ELN* seem to be the most sensitive ‘short/medium time’ and ‘long time’ metrics to sleep loss.

Bibliography

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