Automatic biorhythms description from actigraphic data

M. Gonzalez1,2, J.Q.M. Ly1, G. Gaggioni1, C. Meyer1, V. Muto1, M. Jaspar1, G. Vandewalle1, P. Maquet1,3,4, C. Phillips1,2, S.L. Chellappa1

1Cyclotron Research Centre, University of Liège, Belgium; 2Department of Electrical Engineering and Computer Science, University of Liège, Belgium; 3Walloon Excellence in Lifesciences and Biotechnology (WELBIO), Belgium; 4Department of neurology, CHU, University of Liège, Belgium.

INTRODUCTION

To monitor a subject’s sleep/wake cycles over several days, actigraphic data are routinely recorded with the help of an “acti-watch” placed on the subject’s wrist. These data are scored manually to extract key parameters, e.g. sleep and wake time.

Manual scoring has two main disadvantages:

- Time consuming and tedious task for a trained expert
- Subjective procedure leading to non-reproducible results within and between experts

Ideally artefact detection should be automatic, fast, reproducible and accurate. The Crespo algorithm [1] is one such solution.

The aim of this work was to produce a software that:

- works for (healthy) subjects with regular sleep episodes
- automatically detects the sleep/wake transitions from actigraphic data in a fast, accurate and reproducible way,
- intuitively displays the results,
- is free and open-source (GNU GPLv2 license).

METHODS

Assumptions

Data are acquired:

- on healthy subjects, with normal sleep/wake cycle
- over several days, e.g. 1 week.

Overall organization

Proceed in 3 successive steps:

1. Pre-processing

Importing and cleaning of raw actigraphic data, mainly:

- Reading in the raw actigraphic signal, and beginning date & time of the recording
- Removing flat signal at the beginning, e.g. actigraph switched on too early
- Filling “too long” episodes of flat signal, e.g. acti-watch momentarily not worn

2. Pre-scoring

Apply classic signal processing to estimate the sleep/wake period:

- Padding begin/end with high signal
- Filtering with a median operator
- Applying a rank-order threshold (33% as about 8h of sleep over 24h)
- Morphological filtering, closing followed by opening (e.g. here under)

3. Final scoring

Use a “neural network” (NN) [2] to refine the transition times:

- Extract the actigraphic signal ‘far’(by 1h) from the transition times (in green over the partial actigraphic plot here under)
- split signal and build local features, i.e. median, interquartile range, mean, standard deviation, max, min, mode & itersos, in 15min windows
- train the NN on these features with their ‘wake’ or ‘sleep’ label
- split the signal in 15min windows around the transitions and build local features
- apply the trained NN on these features and derive new labels, ‘sleep’ or ‘wake’, for each time bin.

Output

- Binary Sleep/Wake time series (same resolution as the actigraphic data)
- Other parameters: daily wake and sleep times

REFERENCES


RESULTS

Presentation of actigraphic data

One subject over several days, with sleep/wake transitions: standard daily presentation (left) and continuous spiralling time line (right).

Validation of the method

Comparison between the “automatic scoring” and “manual scoring” (considered as the “gold standard”): score (‘sleep’ or ‘wake’) at each time bin of the actigraphic data & sleep and wake time.

Data:

- 25 young healthy subjects, following regular sleep/wake cycles (for a specific study)
- recording of actigraphic data over more than a week
- manual scoring by an expert over the last 7 days of recording

Criteria

- error rate, i.e. disagreement in scoring
- sensitivity/specificity of ‘wake’ detection
- Cohen’s Kappa [3] (inter-rater reliability)
- difference in median sleep & wake time (over 7 days)

Mean values (with minimum and maximum) for the 25 subjects.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Mean</th>
<th>min / max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error rate</td>
<td>2.31%</td>
<td>1.20% / 5.01%</td>
</tr>
<tr>
<td>Specificity</td>
<td>96.26%</td>
<td>88.43% / 99.35%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>98.43%</td>
<td>93.81% / 99.51%</td>
</tr>
<tr>
<td>Kappa</td>
<td>94.83%</td>
<td>89.01% / 97.30%</td>
</tr>
<tr>
<td>Median wake time difference</td>
<td>9m 38s</td>
<td>-14m 49s / 45m 0s</td>
</tr>
<tr>
<td>Median sleep time difference</td>
<td>11m 22s</td>
<td>-10m 0s / 34m 0s</td>
</tr>
</tbody>
</table>

CONCLUSION

The automatic method is automatic and faster than manual scoring. Results are reproducible and similar to those obtained by a trained expert.

The code is available here: http://CyclotronResearchCentre.github.io/Actigraphy

“To do” list:

- more validation by comparing with (and between) multiple human raters,
- derivation of other sleep/wake parameters of interest
- refining/improving the algorithm for all types of data