Activity Measurement and Monitoring Technologies

Ilkka Korhonen, Research Professor
Contents

• Basis for activity monitoring
• Review of existing methods
• IST Vivago activity measurement - measurement principles
• Comparison of IST Vivago activity signal with other methods in sleep/wake detection
Basics

• Measurement of the activity of an ambulatory subject is based on measurement of **accelerations** or **forces** caused by the movements
  • Measurement site
  • Measurement technology
• **Actigraph** = small, wrist-worn device that measures movement
  • (Wrist) actigraphy
  • May also be worn in other sites e.g. ankle (PLMS)
• Application: recording of long-term (days-weeks) body movements with minimal disturbance in free moving subjects
  • sleep quantity and quality
  • other movement-related disorders and fatigue
  • evaluation of drug effects
  • circadian rhythm
Actigraphy: measurement technology

- Standard actigraphs use accelerometers for detection of movement
- One-axial actigraphs: measurement in one direction
  - More simple and cheaper
  - Most commonly used devices e.g. ActiWatch, Mini-Motionlogger
- Tri-axial actigraphs: measurement in 3D
  - More expensive
  - e.g. Tritrac-R3D, Tracmor
Actigraphy: composition of the activity signal

- Actigraph quantifies the acceleration signal into digits and constructs an *activity signal*.
- **Most common approach:** *Count* of activities exceeding a certain threshold (typically 0.1g) within a fixed period of time (typically 30sec or 1min).
- Also area under curve (integral), time above threshold, zero crossing rate, ...
- Data from different systems difficult to compare
  - However, from applicability point of view, results are usually comparable with different systems.

Source: www.ambulatory-monitoring.com
Acceleration signal
Actigram signal

Source: www.ambulatory-monitoring.com
Sleep/wake scoring by actigram

Source: www.ambulatory-monitoring.com
Measurement guidelines

- Site: nondominant hand (wrist) recommended e.g. for sleep studies
- Analysis resolution: 30sec or 1min
- For reliable results min. 3 consecutive 24h periods
- Limiting factors:
  - Identification of "unit off" periods difficult in standard systems
  - Length of the allowable collection period depends on sampling rate; typically max. order of a week or two
- Artifacts
  - Breathing artifact
  - Co-sleeping
  - Sleep disorders
  - Periodic leg movement syndrome (PLMS) or other movement disorders, incl. Parkinson's disease
Performance of actigraphy in sleep/wake detection

- Golden standard: polysomniography (PSG)
- Actigraphy used as a diagnostic tool
  - long-term measurements
  - normal environment
- Minute-by-minute agreement rates with PSG in **normal subjects** ~90%
- Total sleep time (TST) estimation with average error ~15min have been reported
  - However, error may be much higher in individual cases!
- Lower agreement if
  - Sleep disorders
  - Movement disorders
  - Artifacts
BASIC Mini-Motionlogger® Actigraph

Cambridge Neurotechnology Actiwatch®

Source: www.ambulatory-monitoring.com
Activity signal from Vivago®

1. Wrist unit measures forces between the wrist unit and the wrist
2. Force signal is transformed into messages, which are transmitted to the base station
3. IST Vista software (in institutional system) transforms messages into an activity signal
   - both force level and intermessage timing are used in the transformation
   - The resulting activity signal has a time resolution in the order of ~2min
Vivago activity signal in a normal subject
Vivago activity signal in a demented 81-year old subject
Activity signal and automatic alarms

• Originally, Vivago has been designed for automatic alarms, which are based on the activity signal generated.
  • Improved sensitivity in low levels of activity for discrimination of sleep and unconsciousness
• Detection based on unusually low levels of activity or no activity at all
  • Alarm delays adaptive and depend on the normal activity cycle of the subject
  • Different function during day and night

• (A short validation study to test the alarms against specifications for a home unit; passed; VTT 2002)
Example of an automatic alarm based on activity

Woke up 3:50, fell and stayed unconscious; deterioration alarm at 5:00, help arrived 5:30
Other technical features of the Vivago®

- Features designed primarily for alarm usage are also useful for activity monitoring
  - "Off wrist" detection → monitoring of real usage (minimisation of artifacts in interpretation)
  - Online monitoring → no need to separately transfer data to computer
    - True long-term monitoring, unobtrusiveness
- Field trial in Savitaipale (2001), 83 elderly users
  - Utilisation rate ("on wrist") 94%
  - Number of passivity and deterioration alarms correlates to functional capacity
  - Out of 6 falls during the trial, 5 caused an alarm

![Graph showing the relationship between functional capacity and number of passivity alarms.](image-url)
IST Vivago® vs. actigraphy

- Vivago signal has been optimised for alarms, hence:
  - At low levels of activity Vivago is more sensitive (detects smaller movements)
  - At high levels of activity actigraphy has larger dynamics
IST Vivago® vs. actigraphy
Validation study for Vivago in sleep/wake detection

• Goal: to define how well Vivago performs in sleep/wake detection as compared to standard actigraphy/Golden standard

• Study design:
  • 28 subjects (age<65 N=13 normal; age>65 N=15)
  • 1 night in sleep laboratory (PSG, golden standard)
    • Haaga Neurological Research Center, Helsinki, Finland
  • 1 week of actigraphy (nap analysis)

• Comparison in terms of
  • Night-time minute-by-minute agreement-% with PSG
  • Nap analysis (ref. diary)
Methods for sleep/wake detection

- Actigraphy by ActiWatch (Cambridge Neurotechnology); in large clinical use
- Standard sleep laboratory PSG scored by sleep specialist for reference; golden standard
- Sleep/wake scoring
  - Methods for automatic detection were optimised on the basis of agreement-%
  - Identical methods were applied both for actigraphy and Vivago
    - Minimisation of the effect of scoring algorithm
  - Sample bias was minimised by leave-one-out optimisation
Example of signals in sleep laboratory
### Results: agreement with PSG

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<th>AGREEMENT (%)</th>
<th>All subjects (N=28)</th>
<th>WristCare</th>
<th>Actigraphy</th>
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<td>Thresholding</td>
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<tr>
<td>Logistic regression</td>
<td>85/10</td>
<td>86/11</td>
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</table>
Results: nap analysis

- Agreement-% between Vivago and actigraphy was 87%
  - Naps <10min were ignored

- Vivago and actigraphy provided equal detection of naps in terms of duration and number of naps

- Naps reported in sleep diaries (N=13);
  - Actigraphy correctly detected 11 of them
  - Vivago correctly detected 12 of them
Conclusions

• The performance of the Vivago activity signal can be assumed to be well comparable to actigraphy in sleep/wake studies.

• The study suggests that the device may be used in long-term monitoring of sleep/wake patterns with similar performance to actigraphy.

• Advantages of Vivago: inexpensive, true long-term online monitoring, available in daily normal environment, "off wrist" detection
  • Screening, follow up, ...

• Cautions: validation study based on relatively small sample - longer and larger studies are needed to confirm the results and to extrapolate to other applications.