HIGH RESOLUTION DETECTION OF POLYSOMNOGRAPHY BASED PHASIC EVENTS OF REM SLEEP IN POSTTRAUMATIC STRESS DISORDER

IMPROVING TOOLS FOR PSG ANALYSIS OF REM SLEEP IN PTSD

Hyatt Moore IV1, 2
Steve Woodward3, PhD
Emmanuel Mignot1, MD, PhD

1Electrical Engineering
Stanford University, CA
2Center for Sleep Science and Medicine
Stanford University, CA
3Veteran Affairs National Center for PTSD
Menlo Park, CA;
2. Posttraumatic Stress Disorder (PTSD)

- Unique anxiety disorder that develops when a person is unable or fails to recover from the stress induced by a specific traumatic event.

- Diagnosis under DSM-IV
  - A. Exposure to traumatic event
    - Actual or threatened death or serious injury, or physical threat to one’s self or others
    - Response of intense fear, helplessness, or horror
  - B. Intrusive recollection (re-experience)
  - C. Avoidance/numbing
  - D. Hyper-arousal
  - E. Duration – more than 1 month
  - F. Functional significance

- Population prevalence in U.S.
  - 5% of men
  - 10% of women
3. Sleep and Rapid Eye Movements

Different levels of sleep analysis – and where an Electrical Engineer may be helpful

Time in Bed?

Time in **sleep**?

Cycles

NREM – Non rapid eye movement

**REM** – Rapid Eye Movement Sleep

- Tonic
- Phasic

Reported Differences in Sleep with PTSD
- Higher REM Density (REMD) in PTSD
- Decreased slow wave sleep (SWS) – stage 4
- Reduced time in Stage 2
- Increased REM Density
- Decreased REM latency
4. Polysomnography Dataset

- 176 Vietnam era veterans
  - 42-48 years of age (45.2, \( sd = 3.1 \))
  - Unmedicated, nonapneic
  - 3-4 sleep studies (1993-1995)
- 17 – No combat
- 159 – Combat
  - 143 inpatients with PTSD (DSM-IV criteria)
  - 16 participants without PTSD

Polysomnography montage with REM epoch
5. Electro-oculography (EOG) and its many montages

The human eye, modeled as a dipole, with positive polarity at the pupil, and negative polarity at the retina.

Ocular Activity = Electrode \(\rightarrow\) Reference

**Uenoyama (1963)**
*Pros:* Horizontal, Vertical, and oblique eye movements  
*Cons:* Assumes conjugative, synchronous eye movements; Electrode placement

**Rechtschaffen and Kales (1969)**
*Pros:* Common, simple, robust  
*Cons:* One dimensional (horizontal)  
Assumes synchronous eye movements

**Padovan and Pansini (1972)**
*Pros:* Horizontal, Vertical, and oblique eye movements  
*Cons:* Less known

**Salzarulo (1973)**
*Pros:* 2D tracking of each eye  
Insight to ocular synchrony during REM  
*Cons:* More channels, interpretive complexity
6. EOG Activity Interpretations

**Our approach** *(Uenoyama derivative)*

**Pros:**
- Horizontal, Vertical, and oblique eye movement
- Horizontally robust to EEG contamination

**Cons:** Conjugative synchrony assumed

**Tonic REM – no eye movements**

**Horizontal eye movement**

**Vertical, slow eye movements (SEM) during REM**

**Oblique, rapid eye movement**

**Phasic REM with possible non conjugative eye movements**

Reportings of disconjugate, binocularly asynchronous eye movements during REM sleep:
- Gabersek & Scherrer, 1970
- Gabersek, 1972
- Zhou & King, 1997
- Ktonas et al, 2003
7. Automated approaches to detecting phasic activity in REM

Detector 1 – Liberal; groups detections; susceptible to slow eye movements
Detector 2 – Identifies sharp/rapid changes in activity; susceptible to noisy data
Detector 3 – Conservative; short, precise detections
Detector 4 – Compromises between detectors 1 and 2
Detector 5 – Hindered by frequency-time resolution tradeoff; rejected from further analysis.

8a. Preprocessing Techniques

**Filtering and De-noising Methods**

- Unfiltered HEOG
- High pass filtering (> 1Hz)
- Wavelet de-noising

**Adaptive Noise Cancelling**

Signal with Noise = s + n

Correlated Noise = n’

Adaptive processor

\[ d = \text{Desired response} \]

\[ y = \text{output} \]

\[ e = \text{error} \]

Sum (d-y)

Low pass filtering (< 9Hz)

Band pass filtering (>1Hz, <9 Hz)

Vertical EOG

F3 EEG

K-complex diminished

Unfiltered HEOG

High pass filtering (> 1Hz)

Wavelet de-noising

Low pass filtering (< 9Hz)

Band pass filtering (>1Hz, <9 Hz)

Vertical EOG’
8b. Preprocessing Techniques

Filtering and De-noising Methods

- Unfiltered HEOG
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Adaptive Noise Cancelling

Signal with Noise = s + n

Correlated Noise = n'

Adaptive processor

d = Desired response

y = output

e = error

K-complex diminished
9. Experiment design

Optimization

a. Dataset: Non-combat, non PTSD, second night sleep studies (n=16)

b. Apply EM detectors with and without preprocessing techniques

c. Evaluate changes to EM detection in REM compared to NREM sleep

d. Select processing method based on greatest shifts of EM detections toward REM sleep

Detector optimization

 Detected rapid eye movements

• Horizontal EM
  • Wavelet de-noising most impactful

• Vertical EM
  • Adaptive noise cancelling most impactful
10. Detector performance after optimization (HEOG shown)

- EM detections in REM improve
- NREM EM detections reduced
## 11. Current Status

<table>
<thead>
<tr>
<th></th>
<th>Unaltered</th>
<th>Wavelet</th>
<th>Adaptive</th>
<th>Wavelet with Adaptive*</th>
<th>Shift*</th>
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</thead>
<tbody>
<tr>
<td>VEOG in REM</td>
<td>36.8%</td>
<td>44.3%</td>
<td>55.7%</td>
<td>56.0%</td>
<td>+19.2%</td>
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<tr>
<td>HEOG in REM</td>
<td>48.3%</td>
<td>65.0%</td>
<td>55.3%</td>
<td>67.4%</td>
<td>+19.1%</td>
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<table>
<thead>
<tr>
<th></th>
<th>REM</th>
<th>NREM</th>
<th>REM*</th>
<th>NREM*</th>
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</thead>
<tbody>
<tr>
<td>VEOG Density (Count/hr)</td>
<td>716</td>
<td>713</td>
<td>285</td>
<td>66</td>
</tr>
<tr>
<td>HEOG Density (Count/hr)</td>
<td>891</td>
<td>740</td>
<td>530</td>
<td>158</td>
</tr>
</tbody>
</table>
12. Conclusion

Phasic REM parameters detected automatically are prone to error.

Horizontal EOG is robust against EEG interference
Significantly benefits from wavelet de-noising

Vertical EOG is susceptible to EEG interference and
Significantly benefits from adaptive noise cancellation

Continued work is needed to investigate phasic REM in the sleep of PTSD
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