CGX | Onton Sleep Profiler White Paper

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The Onton Sleep Profiler
Developed by Julie Onton. PhD

In my early work, I analyzed high-dimensional EEG data using MATLAB and tools from the EEGLAB toolbox. I explored topics like short-term memory and emotional imagery.

Later, my research focused on the EEG characteristics of PTSD and mild traumatic brain injury, which led me to study sleep EEG using a single channel on the forehead.

I applied the same approach to sleep as I did to wake EEG, examining patterns of frequency over time. This led to the discovery that an entire night's sleep could be effectively visualized as a single spectrogram, with five frequency bands corresponding to the sleep stages shown in the spectrogram.

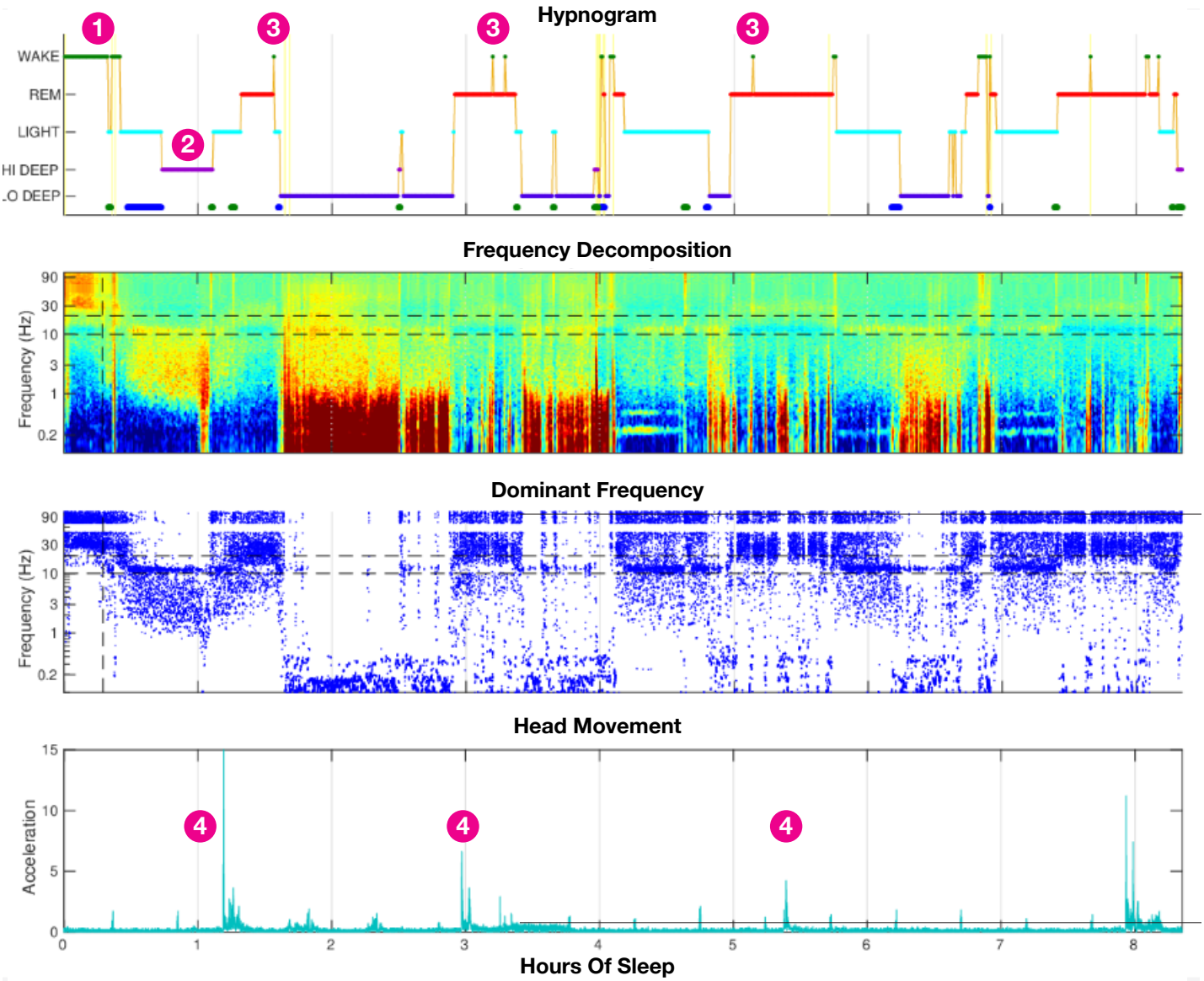
Using this method, I found that individuals with severe PTSD exhibited less of a unique stage of deep sleep that I named "Lo Deep." This finding has inspired me to continue investigating sleep and the frequency components that may reveal new insights into sleep quality and overall health.

I developed the Onton Sleep Profiler in conjunction with CGX using the Patch EEG device. We accumulated over 400 sleep nights from 100+ individuals over a 2-year period. I worked with Sara Mednick, PhD at UC Irvine to validate the algorithmic scoring of the Onton Sleep Profiler against traditional sleep scoring. You can find that validation in the citations section of this publication.

Please feel to reach out to me if you have any questions about the Onton Sleep Profiler.

Characteristics Of A Good Night Of Sleep

Sleep Subject 1



Sleep Subject 1

❶ Ideally, the recorded file shows minimal wake before sleep. Excessive wakefulness and significant movement may indicate the sleeper turned the device on too early, before getting into bed and attempting to sleep.

I recommend using the Trim Function to remove non-essential Wake data at the beginning and end of the recording session. By doing this, the algorithm can more accurately determine sleep stages, as it relies on the entire night as a baseline. Excessive 'noise' during these periods can interfere with sleep pattern analysis.

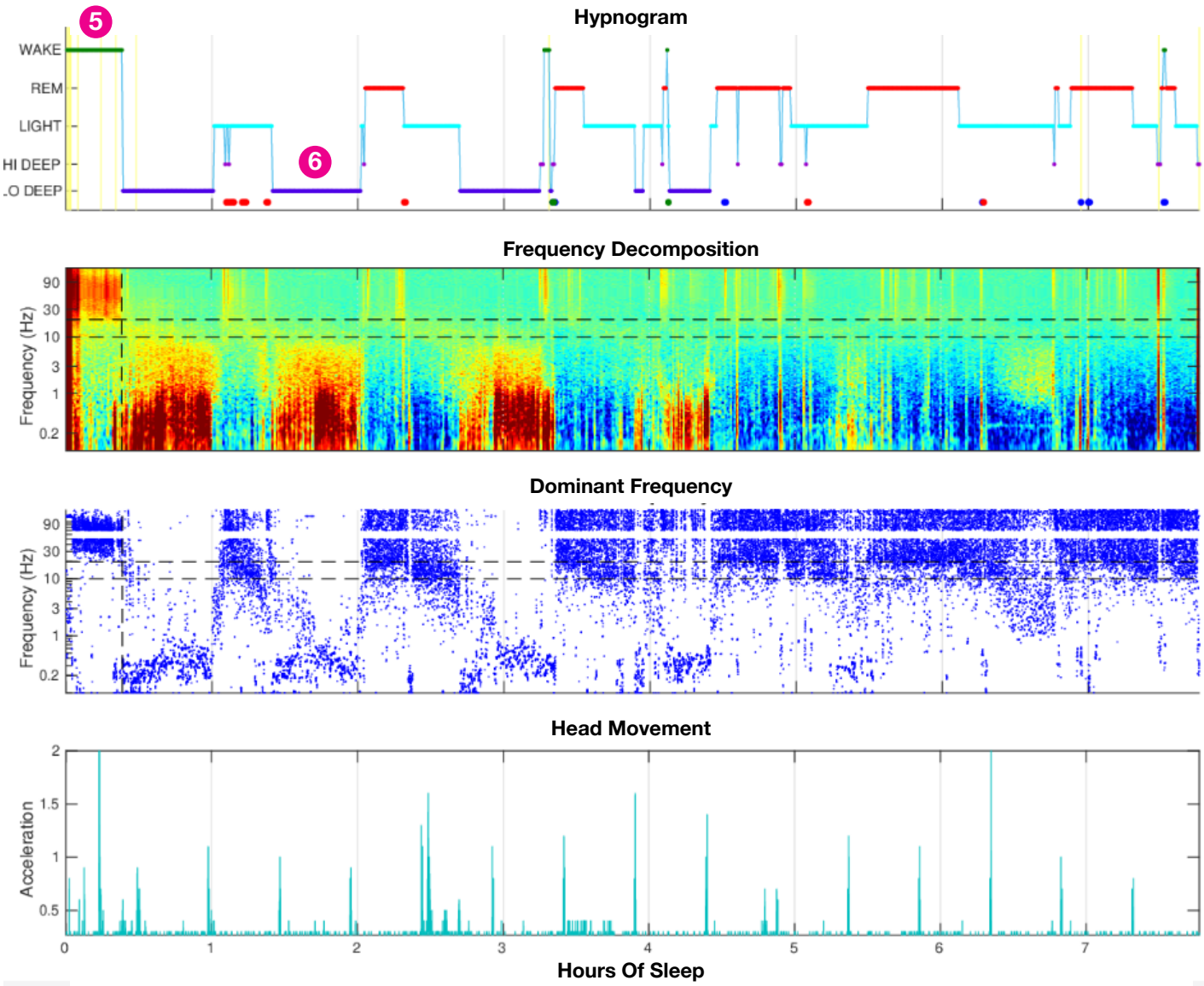
❷ Typical sleep patterns are characterized by mostly deep sleep during the first half of the night and predominantly REM sleep during the second half. As a result, REM periods early in the night are usually short, lasting just a few minutes, while those toward the end of the night can last an hour or more.

High and low stages of deep sleep usually occur in significant bouts of 30 to 60 minutes or longer. Some individuals have shorter or longer cycle lengths, which are not necessarily pathological but instead reflect natural individual differences.

A concerning pattern would be repeated awakenings following very short Hi or Lo Deep sleep stages, which might indicate a pathological process is disrupting the full sleep cycle.

❸ Single epochs of Wake, particularly during REM sleep, are not concerning on their own. They may simply reflect temporary variations in the power levels of brain waves (beta, gamma, and spindles) and do not necessarily indicate a disruption of the current sleep stage.

Sleep Subject 2



Significant micro-awakenings can be identified on a spectrogram by noticeable increases in power across most or all frequency ranges, particularly in the high frequencies, with colors closer to red than yellow indicating stronger signals.

If numerous micro-awakenings are observed in a sleep recording, it may indicate an issue with sleep continuity.

4 Large, rapid accelerometer spikes indicate quick head movements, which can occur when changing positions in bed. This recording shows most deep sleep occurring in the first half and most REM sleep in the second half. There are minimal awakenings, with clear and regular cycles alternating between deep sleep (or light sleep toward the end of the night) and REM.

5 Sleep onset latency was acceptable at under 30 minutes. This duration might be slightly longer than usual if it was the individual's first time wearing the Patch EEG, and there was some movement during this period. However, the amount of movement observed is consistent with someone being in bed and trying to fall asleep.

6 High Deep sleep is noticeably absent in this hypnogram, but this can be normal because the 1-3 Hz frequency range often increases during Low Deep sleep when 0-1 Hz activity is dominant.

The reverse is rarely true; in other words, the 1-3 Hz range is almost never dominant while 0-1 Hz power is also elevated, simply because slow oscillations have a much higher magnitude relative to delta oscillations. When Hi Deep sleep is scored, it is generally when 1-3 Hz is dominant and 0-1 Hz is relatively absent.

Characteristics Of A Good Night Of Sleep

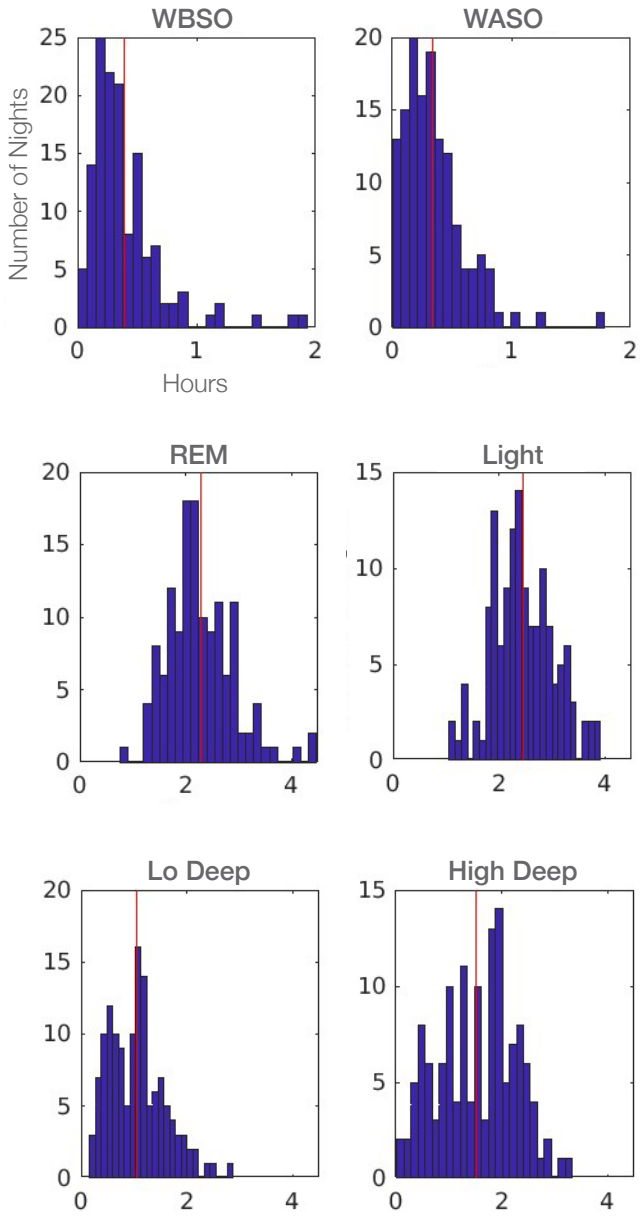
Example of normal sleep stats from healthy subjects

Control data is from 193 nights from 72 subjects who ranged in age from 19 to 48 with a mean age of 29.9. There were 32 females and 40 males.

WASO and the sleep stages are percentage of the entire recording.

Total sleep time does not include WBSO and WASO time.

Total Sleep percentage is calculated as (REM + Light + Hi Deep + Lo Deep)/(REM + Light + Hi Deep + Lo Deep+ All Wake).

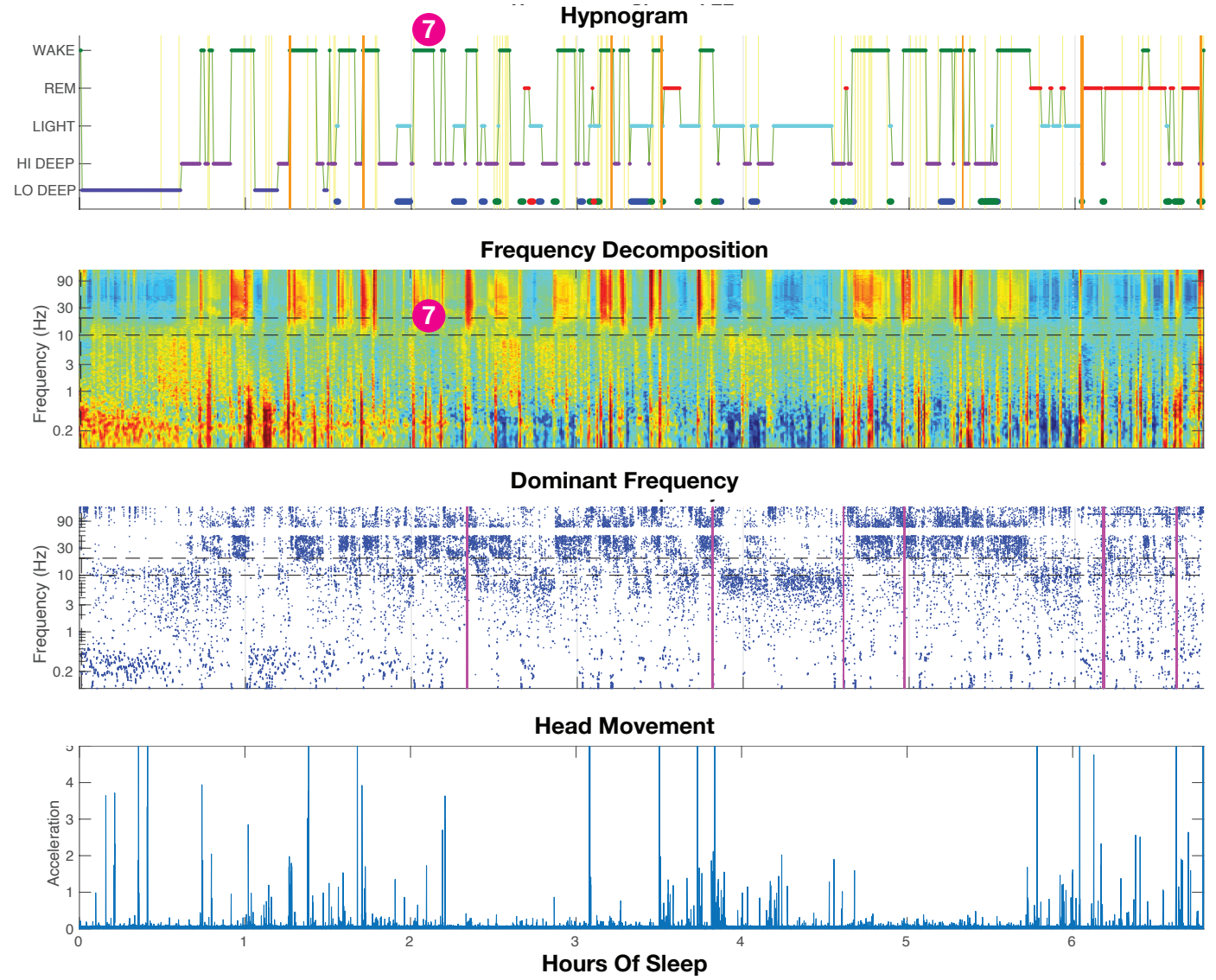


Averages Across Subjects

	Hour:Minute	Percent
WBSO (Wake before sleep onset)	0:24	5.0%*
WASO (Wake after sleep onset)	0:21	4.3%
All Wake	0:45	9.3%
REM	2:17	28.4%
Light	2:27	30.4%
Hi Deep	1:03	13.0%
Lo Deep	1:31	18.8%
Total Sleep	7:18	90.7%

*WBSO is a percentage of the entire recording (total time asleep and awake)

Sleep Subject 3

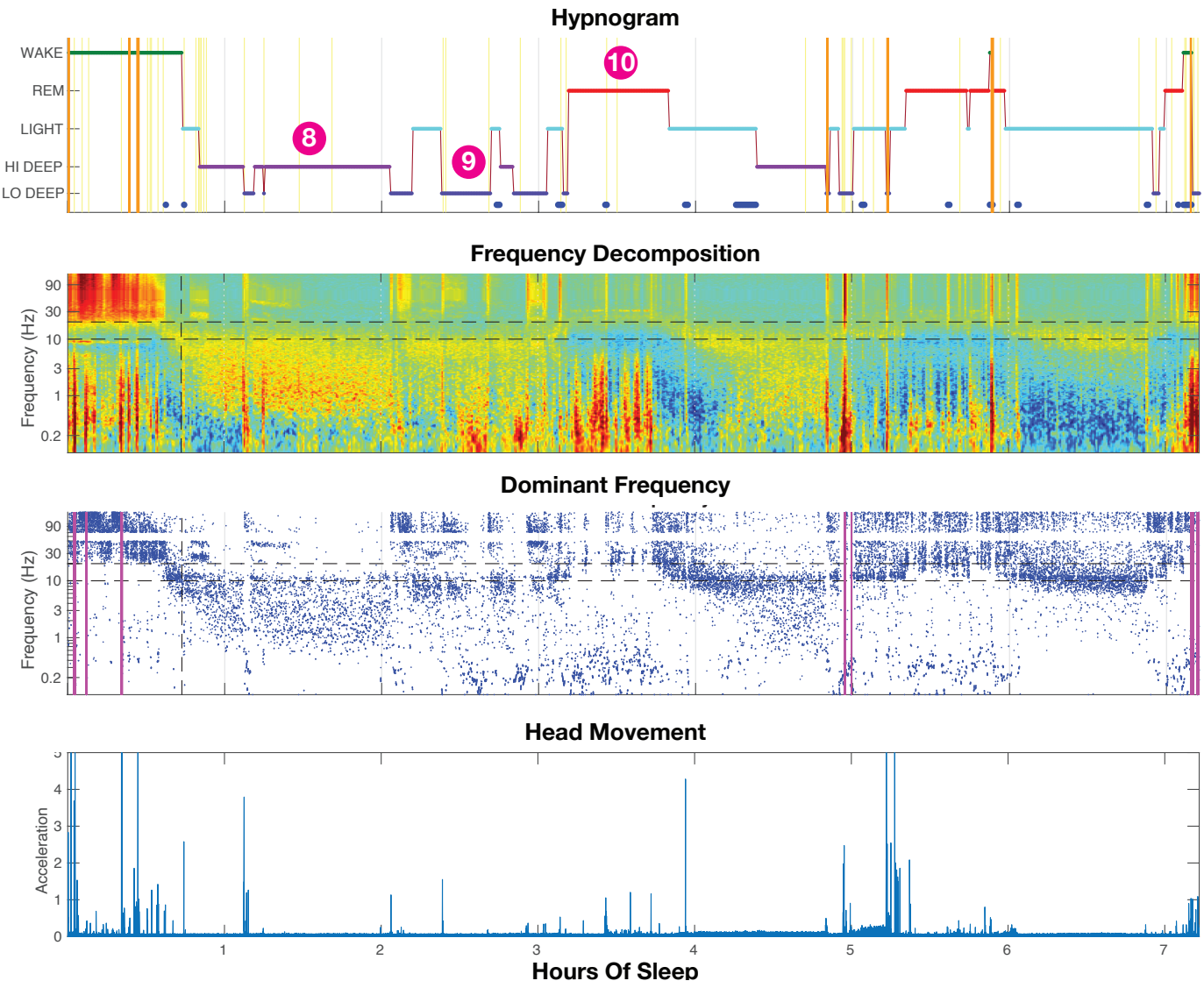


Excessive Wake

7 This report shows excessive Wake activity that can be seen not only in the hypnogram, but in the high frequency activity in the spectrogram.

The excessive Wake obliterated the cycle rhythmicity in favor of brief moments of sleep between awakenings.

Sleep Subject 4



Not Enough Lo Deep Sleep

8 This night shows very little Lo Deep sleep. The absence of Lo Deep sleep is concerning because research has shown that veterans with PTSD, who are often on multiple medications, exhibit a lack of Lo Deep sleep compared to healthy controls.[1] [2]

This deficiency may contribute to the common reports of low sleep quality among those with PTSD.

9 In this sleep example, there is a small amount of true Lo Deep between hours 2 and 3.

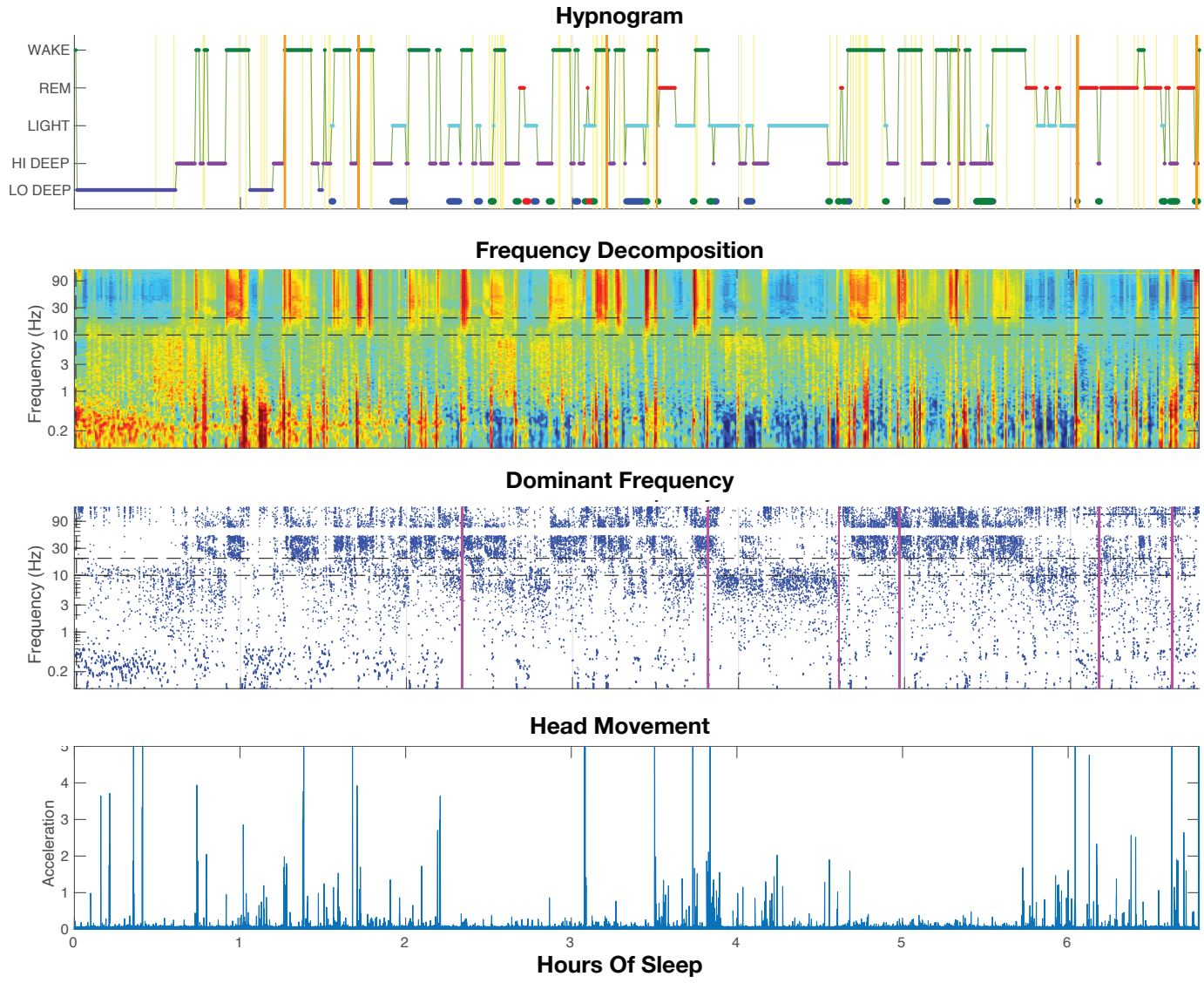
10 Between hours 3 and 4, what appears to be power below 1 Hz is actually REM sleep.

This phenomenon may result from eye movements or another type of low-frequency activity, but it is different from the slow oscillations that characterize Low Deep sleep. While it is not typical, it is not uncommon in certain populations.

[1] Onton, J. A., Matthews, S. C., Kang, D. Y., & Coleman, T. P. (2018). In-home sleep recordings in military veterans with post traumatic stress disorder reveal less REM and deep sleep< 1 Hz. *Frontiers in Human Neuroscience, 12, 196*

[2] Onton JA, Kang DY, Coleman TP. Visualization of Whole-Night Sleep EEG From 2-Channel Mobile Recording Device Reveals Distinct Deep Sleep Stages with Differential Electrodermal Activity. *Frontiers in Human Neuroscience. 2016 Nov 29;10:605.*

Sleep Subject 3

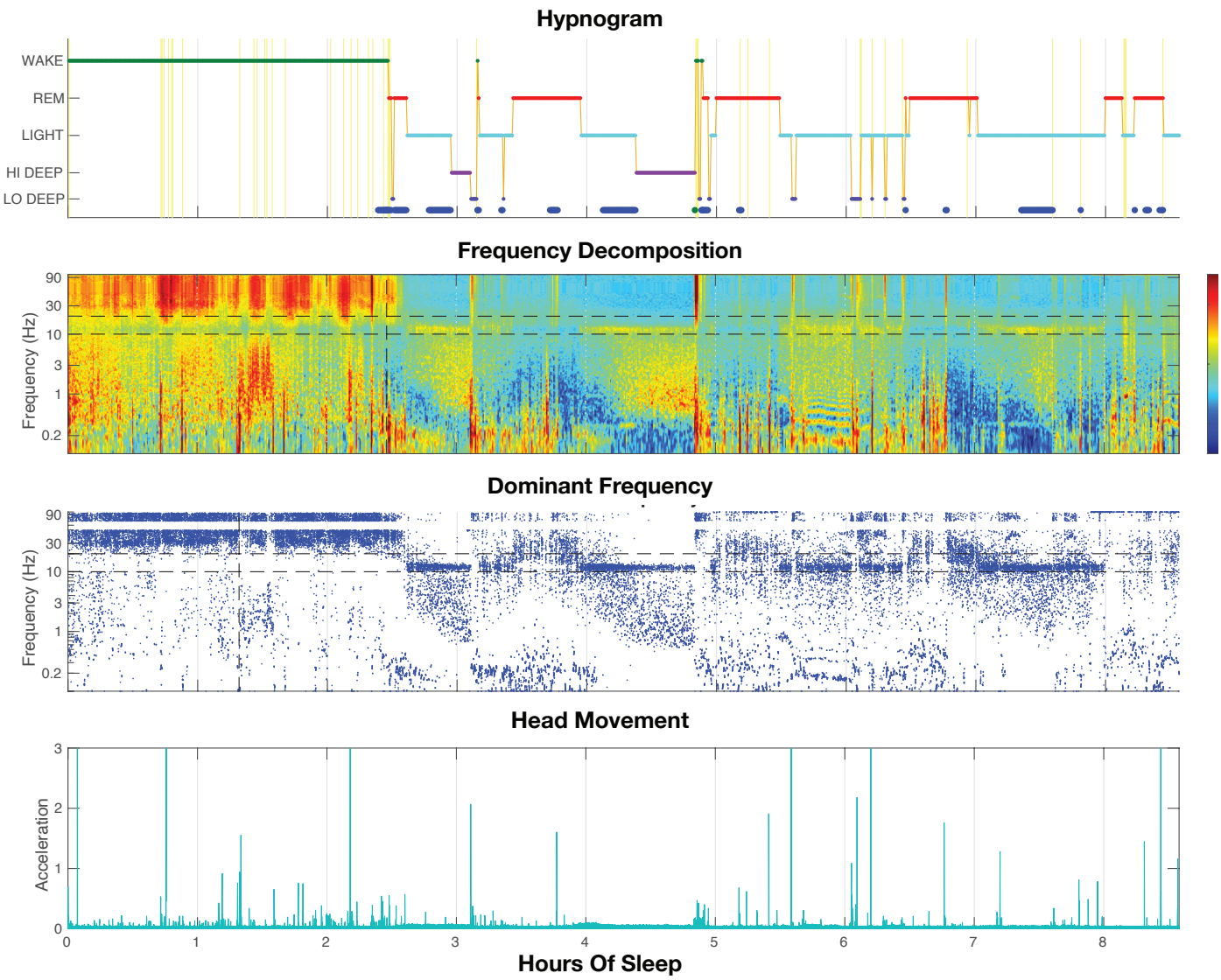


Excess Movement

This subject reports having restless legs syndrome, which is consistent with above-normal movement in the accelerometer graph, along with periodic awakenings and movements consistent with getting out of bed.

However, not all reports showing this pattern of wakefulness and accelerometer activity necessarily mean the individual has restless legs syndrome. It would be helpful to confirm with the individual what occurred during these times.

Sleep Subject 6



Sleep Onset Insomnia

This individual suffers from insomnia, as indicated by an almost two-and-a-half-hour period of wakefulness with medium to low accelerometer activity. Combined, this indicates difficulty falling asleep.

Contact Information

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Publications

Validation of spectral sleep scoring with polysomnography using forehead EEG device. Frontiers In Sleep. (2024) 3:1349537. doi: 10.3389/frsle.2024.1349537. Onton JA, Simon KC, Morehouse AB, Shuster AE, Zhang J, Pena AA and Mednick SC.

Extracting Stress-Related EEG Patterns From Pre-Sleep EEG for Forecasting Slow-Wave Sleep Deficiency. IEEE Trans Neural Syst Rehabil Eng. 2024; 32:1817-1827.Su CH, Ko LW, Jung TP, Onton J, Tzou SC, Juang JC, Hsu CY. PMID: 38683718.

Editorial: Advances in brain dynamics in the healthy and psychiatric disorders. Front Psychiatry. 2023; 14:1284670. Papo D, Bucolo M, Dimitriadis SI, Onton JA, Philippu A, Shannahoff-Khalsa D. PMID: 37779613; PMCID: PMC10539585.

Triggers and Characteristics of Brain Zaps According to the Findings of an Internet Questionnaire. Prim Care Companion CNS Disord. 2022 Feb 10; 24(1). Papp A, Onton JA. PMID: 35144325.

Unsupervised learning of brain state dynamics during emotion imagination using high-density EEG. Neuroimage. 2022 04 01; 249:118873.Hsu SH, Lin Y, Onton J, Jung TP, Makeig S. PMID: 34998969.

Amount of < 1Hz deep sleep correlates with melatonin dose in military veterans with PTSD. Neurobiol Sleep Circadian Rhythms. 2021 Nov; 11:100072. Onton J, Le LD. PMID: 34368501; PMCID: PMC8326800.

Brain Zaps: An Underappreciated Symptom of Antidepressant Discontinuation. Prim Care Companion CNS Disord. 2018 Dec 20; 20(6).Papp A, Onton JA. PMID: 30605268.

In-Home Sleep Recordings in Military Veterans With Posttraumatic Stress Disorder Reveal Less REM and Deep Sleep <1 Hz. Front Hum Neurosci. 2018; 12:196. Onton JA, Matthews SC, Kang DY, Coleman TP. PMID: 29867419; PMCID: PMC5958207.

Visualization of Whole-Night Sleep EEG From 2-Channel Mobile Recording Device Reveals Distinct Deep Sleep Stages with Differential Electrodermal Activity. Front Hum Neurosci. 2016; 10:605. Onton JA, Kang DY, Coleman TP. PMID: 27965558; PMCID: PMC5126123.

Combat veterans with comorbid PTSD and mild TBI exhibit a greater inhibitory processing ERP from the dorsal anterior cingulate cortex. Psychiatry Res. 2014 Oct 30; 224(1):58-66. Shu IW, Onton JA, O'Connell RM, Simmons AN, Matthews SC. PMID: 25150386.

Combat veterans with PTSD after mild TBI exhibit greater ERPs from posterior-medial cortical areas while appraising facial features. J Affect Disord. 2014 Feb; 155:234-40. Shu IW, Onton JA, Prabhakar N, O'Connell RM, Simmons AN, Matthews SC. PMID: 24342149.

Independent EEG sources are dipolar. PLoS One. 2012; 7(2):e30135. Delorme A, Palmer J, Onton J, Oostenveld R, Makeig S. PMID: 22355308; PMCID: PMC3280242.

Human brain dynamics accompanying use of egocentric and allocentric reference frames during navigation. J Cogn Neurosci. 2010 Dec; 22(12):2836-49.Gramann K, Onton J, Riccobon D, Mueller HJ, Bardins S, Makeig S. PMID: 19925183; PMCID: PMC4136456.

High-frequency Broadband Modulations of Electroencephalographic Spectra. Front Hum Neurosci. 2009; 3:61. Onton J, Makeig S. PMID: 20076775; PMCID: PMC2806183.

Imaging human EEG dynamics using independent component analysis. Neurosci Biobehav Rev. 2006; 30(6):808-22. Onton J, Westerfield M, Townsend J, Makeig S. PMID: 16904745.

Mapping single-trial EEG records on the cortical surface through a spatiotemporal modality. Neuroimage. 2006 Aug 01; 32(1):195-207. Tsai AC, Liou M, Jung TP, Onton JA, Cheng PE, Huang CC, Duann JR, Makeig S. PMID: 16730194.

Information-based modeling of event-related brain dynamics. Prog Brain Res. 2006; 159:99-120. Onton J, Makeig S. PMID: 17071226.

Frontal midline EEG dynamics during working memory. Neuroimage. 2005 Aug 15; 27(2):341-56. Onton J, Delorme A, Makeig S. PMID: 15927487.

Mining event-related brain dynamics. Trends Cogn Sci. 2004 May; 8(5):204-10. Makeig S, Debener S, Onton J, Delorme A. PMID: 15120678.

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