


Novel Ways of Diagnosing Sleep-Disordered Breathing



Koby Sheffy, PhD
Boston 2017

Disclosure

I am the Chief Scientist and Sr VP at Itamar Medical and a co-inventor of PAT

Nothing else to disclose




anything new under the Picturesque Sun Guys ?


SDB was Defined by PSG – it is a Synergy

"Polygraphic Study of the Episodic Diurnal and Nocturnal (hypnic and respiratory) Manifestations of the Pickwickian Syndrome." Gastaut H et al, *Brain Res.* 1965;2:167–86.


And 10 years later comprehensively established:
"The sleep apnea syndromes". Guilleminault, C; Tilkian, A; Dement, WC. *Annual Review of Medicine* 1976; 27: 465–484.



Dr. Gastaut



Dr. Dement

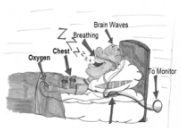


Dr. Guilleminault


Emerging innovations over the years

- Challenging the well established PSG
 - The venue (taking it home)
 - The technology (from analog paper recorder to digital PC and more)
 - The physiological channels and interpretations
- Started as early as the 80's


Driven by



Hard to sleep there



Hard to get there



Hard to pay it

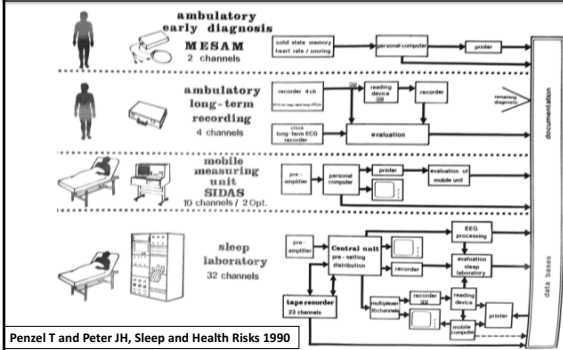
'Thinking out of the PSG Box – the 80's

- Some new innovations
 - Taking it home
 - New technologies
 - New interpretations



Chapeau Dr. Penzel !!!

The 4 Diagnostic Levels Approach



The Marburg Kofer - 1982

inductive plethysmography 2 belts, partial oxygen pressure using Severinghaus electrodes, ECG, 4 channel audio tape at slow speed, infra red LED equipped glasses for vigilance monitoring.





Vitalog HMS-300 "Lunchbox" – 1990

Miles LE, 1990

Table 1. Sleep report

Sleep stages
Latencies
REM
Waveform occurrences
Delta amplitude and frequency
Apneas
Hypopneas
Oxygen desaturation
Heart rate
Periodic leg movements
NPT
Temperature
Body position

Messam - 1988

2 channel digital system with microphone and heart rate

Messam 4 - 1990

Snoring, heart rate, body position, oxygen saturation

What can you do on bed in a long cold Finish night

What can you do on a cold Finish night in bed ?

Count elks

Download from
Dreamstime.com

© 2014-2016
Technische Universität Braunschweig

What can you do on a cold Finnish night in bed ?

Make love



Download from Dreamstime.com

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What can you do on a cold Finnish night in bed ?

Or think



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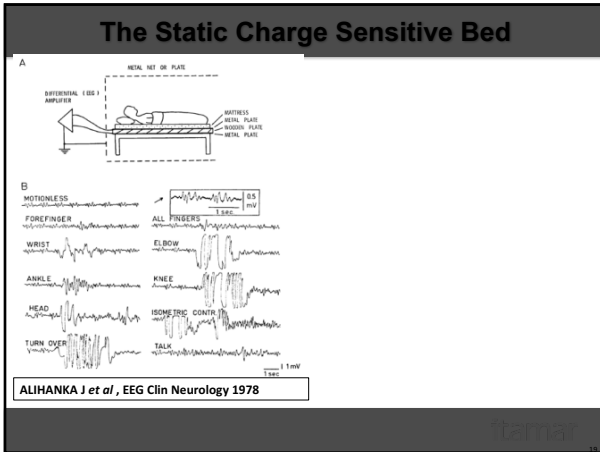
What can you do on a cold Finnish night in bed ?

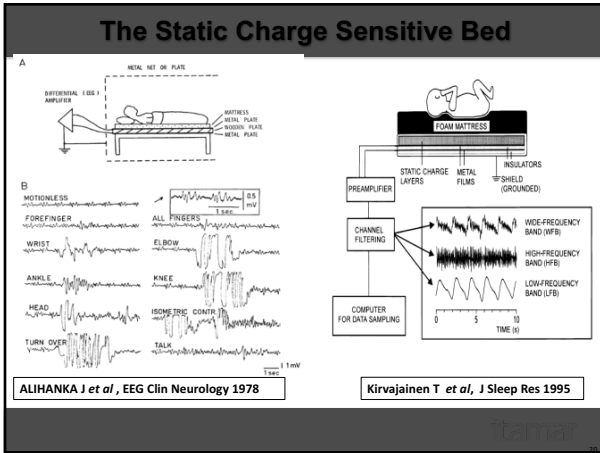
And then realize – in Finland it all happens on the mattress



Download from Dreamstime.com

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Taking it Home – the 90's

The establishment of the ambulatory cardio-pulmonary sleep devices (NAF, Respiratory Belts, ECG, SaO2)

Gaining simplicity/cost
Compromising on


- TST (AHI by TRC)
- Sleep stages (effect on sleep, REM related OSA)




Remmers - bedside
EdenTech - bedside
Synectics - bedside
Embleta - wearable
Stardust - wearable
.....

Challenging the at Home Limitations – the 21 Century

ARES – the Apnea Risk Evaluation System



EEG/EOG (frontal electrodes)
 NAF
 Snoring
 SpO2
 Head Movement



Dr. Philip Westbrook

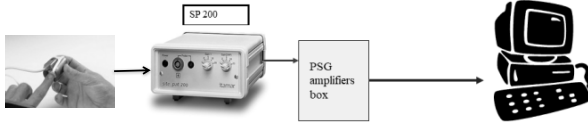
Westbrook PR *et al*, **Description and validation of the apnea risk evaluation system: a novel method to diagnose sleep apnea-hypopnea in the home.** CHEST 2005

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I am the Chief Scientist and Sr VP at Itamar Medical and a co-inventor of PAT

Nothing else to disclose

The PAT Signal and Technology



".... Given that elevated peripheral resistance and tightly linked transient heart rate elevation is a consistent part of the hemodynamic response to arousal and OSAS, we believe that pulsatile finger blood flow patterns can be clearly diagnostic of OSAS and other sleep-disordered breathing conditions."

Schnall RP, Shlittner A, Sheffy J, Kedar R, & Lavie P. **Periodic, Profound Peripheral Vasoconstriction – A New Marker of obstructive Sleep Apnea.** *SLEEP* 1999;

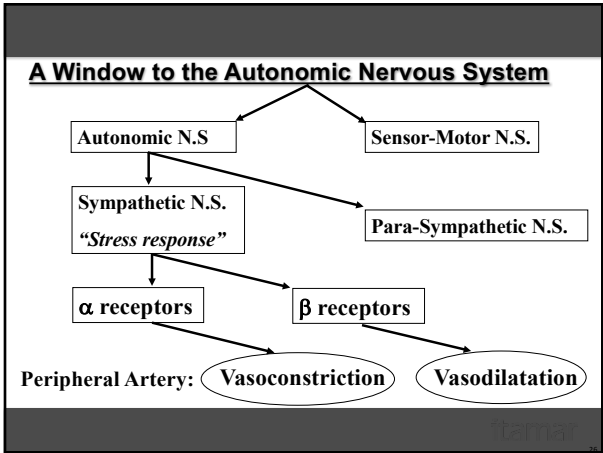
The PAT® (Peripheral Arterial Tone) Signal

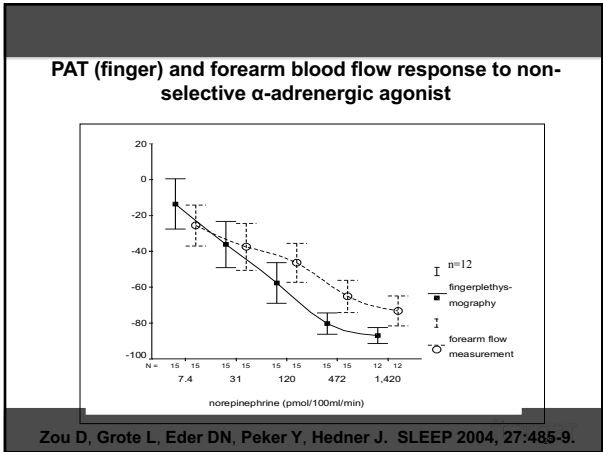
PAT® Signal - pulsatile arterial volume at the Finger Tip

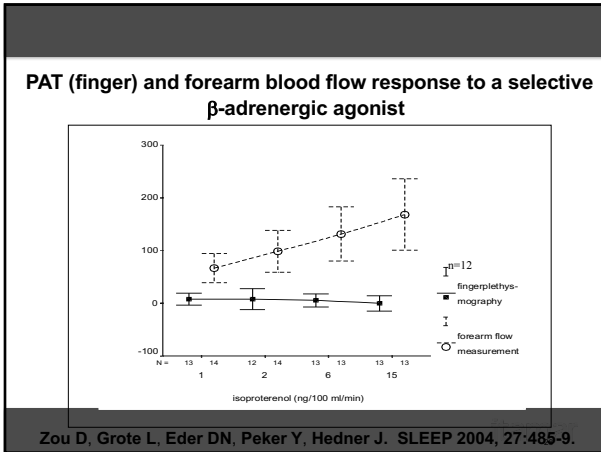
Reflects vasomotor tone at the finger tip

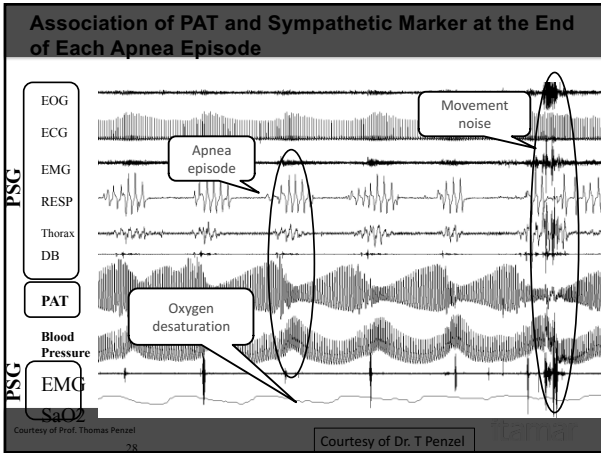
A window to two vaso-regulating systems:

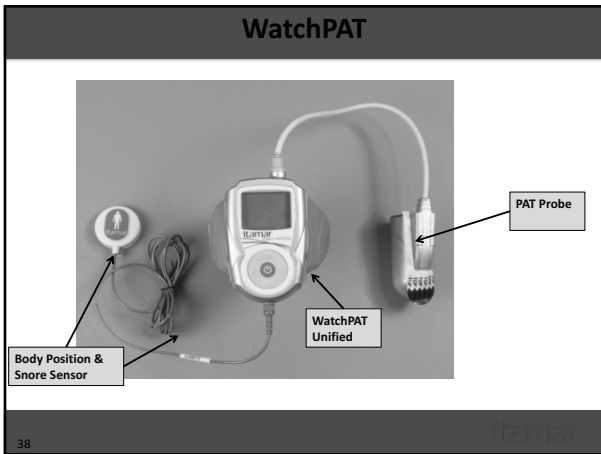
- The arterial endothelial system
- The autonomic nervous system – sympathetic branch












Taking it to the Patient Home



A black and white photograph of a patient lying in bed, wearing a wrist-worn device on their left hand. The patient is wearing a patterned nightgown and is looking towards the camera.

....and Its Features

- Automatic analysis
 - manual editing available
- Clinical Applications:
 - AHI (Apnea Hypopnea index)
 - (Apneas + Hypopneas) / total sleep time
 - RDI (Respiratory Disturbance Index)
 - (Apneas + Hypopneas + RERAs) / total sleep time
 - ODI (Oxygen desaturation index)
 - Wake/Sleep detection
 - REM/Deep/Light sleep stages
 - Snoring
 - Body Position
- Comprehensive Report



A small black and white photograph of a patient lying in bed, wearing a wrist-worn device on their left hand.

•Comfortable - minimal sleep interference

WatchPAT® Screen – Identified Respiratory Events (Sleep Apnea)

channels change

↓ ↓

PAT Signal: Attenuation

PAT Amplitude: Decrease

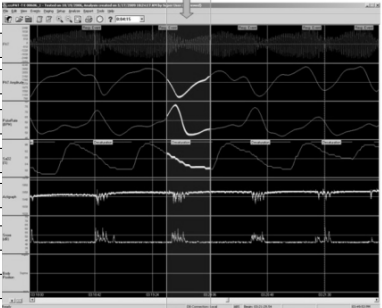
Pulse Rate: Increase

Oxygen: Desaturation

Actigraph: Movement


Snoring: Surge

Position: Supine



A screenshot of a software interface showing a multi-channel waveform graph. The graph displays several channels of data over time, with a vertical line indicating a 'Respiratory event'. The channels include PAT Signal, PAT Amplitude, Pulse Rate, Oxygen, Actigraph, Snoring, and Position. The PAT Signal and Amplitude channels show a significant decrease during the event, while the Pulse Rate channel shows a corresponding increase. The Oxygen channel shows a slight desaturation. The Actigraph channel shows a burst of movement. The Snoring channel shows a surge. The Position channel shows the patient is in a supine position.

Differentiating between Sleep and Wake



- A 3D accelerometer based actigraphy
- A learning machine phase of the background movements (energy)
- PAT/Oxi sleep patterns

Multicenter sleep/wake novel algorithm validation

A Novel Adaptive Wrist Actigraphy Algorithm for Sleep-Wake Assessment in Sleep Apnea Patients

Jan Hedner, MD, PhD¹; Giora Pillar, MD, DSc²; Stephen D Pittman MS³; Ding Zou, MD¹; Ludger Grote, MD, PhD¹; David P White, MD⁴

¹Sleep Laboratory, Pulmonary Medicine, Sahlgrenska University Hospital, Gothenburg, Sweden; ²Sleep Lab, Rambam Medical Center and Technion – Israel Institute of Technology, Haifa, Israel; ³Sleep Division, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA

Study Objectives: Current actigraphic algorithms are relatively less accurate in detecting sleep and wake in sleep apnea patients than in people without sleep apnea. In the current study, we attempted to validate a novel automatic algorithm, which was developed for actigraphic studies in normal subjects and patients with obstructive sleep apnea by comparing it on an epoch-by-epoch basis to standard polysomnography.

Design: Prospective cohort study.

Setting: Multicenter, university hospital, sleep laboratories.

Participants: A total of 228 subjects from 3 different sleep centers (Skara, Boston, Haifa) participated.

Intervention and Measurements: Simultaneous recording of polysomnography and WatchPAT100, an ambulatory device that contains a built-in actigraph. The automatic sleep/wake algorithm is based on both the quantification of motion (magnitude and duration) and the various periodic movement patterns, such as those occurring in patients with moderate to severe obstructive sleep apnea.

Results: The overall sensitivity and specificity to identify sleep was 89% and 69%, respectively. The agreement ranged from 86% in the normal subjects to 86%, 84%, and 80% in the patients with mild, moderate, and severe obstructive sleep apnea, respectively. There was a tight agreement between actigraphy and polysomnography in determining sleep efficiency (78.4 ± 9.9 vs $78.8 \pm 13.4\%$), total sleep time (690 ± 152 vs 690 ± 154 epochs), and sleep latency (56.8 ± 31.4 vs 43.3 ± 45.4 epochs). While for most individuals the difference between the polysomnography and actigraphy was relatively small, for some there was a substantial disagreement.

Conclusions: We conclude that this actigraphy algorithm provides a reasonably accurate estimation of sleep and wakefulness in normal subjects and patients with obstructive sleep apnea on an epoch-by-epoch basis. This simple method for assessment of total sleep time may provide a useful tool for the accurate quantification of obstructive sleep apnea in the home environment.

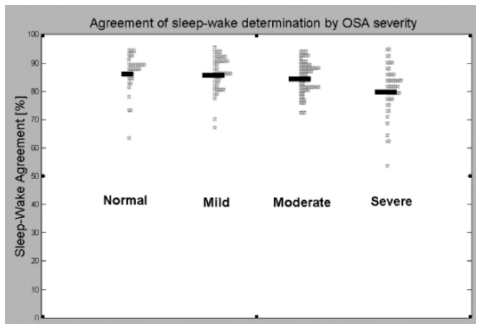
Key Words: Actigraph, polysomnograph, WatchPAT 100, Sleep/wake

Citation: Hedner J, Pillar G, Pittman SD et al. A novel adaptive wrist actigraphy algorithm for sleep-wake assessment in sleep apnea patients. *SLEEP* 2004;27(8):1560-6.

A Novel Adaptive Wrist Actigraphy Algorithm for Sleep-Wake Assessment in Sleep Apnea Patients


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Jan Hedner, MD, PhD¹; Giora Pillar, MD, DSc²; Stephen D Pittman MS³; Ding Zou, MD¹; Ludger Grote, MD, PhD¹; David P White, MD⁴



WatchPAT® identification of Sleep Stages

1. Step 1 find sleep/wake (First we take Manhattan.....)
1. Step 2 find REM/NREM (and then we take Berlin.....)
1. Step 3 differentiate between Deep and Light sleep in the NREM epochs (and maybe then Boston...)

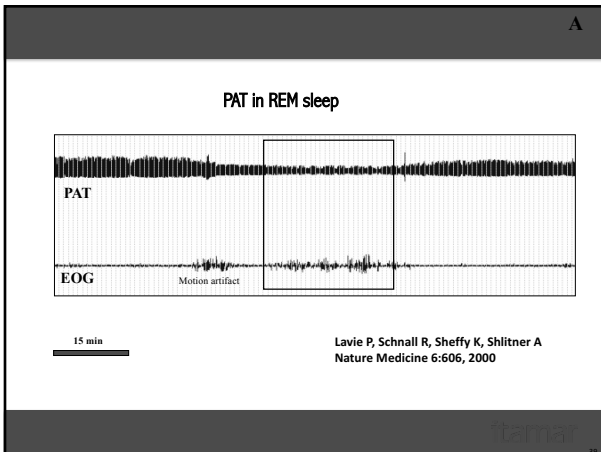


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WatchPAT REM/Deep/light algorithm description

- Differential activation (sympathetic vs. parasympathetic) in sleep stages – subcortical manifestation
- 16 features extracted from the PAT signal
- Time and frequency domain analysis of events – provides a kind of sympathetic signature
- A few features can be eyeballed

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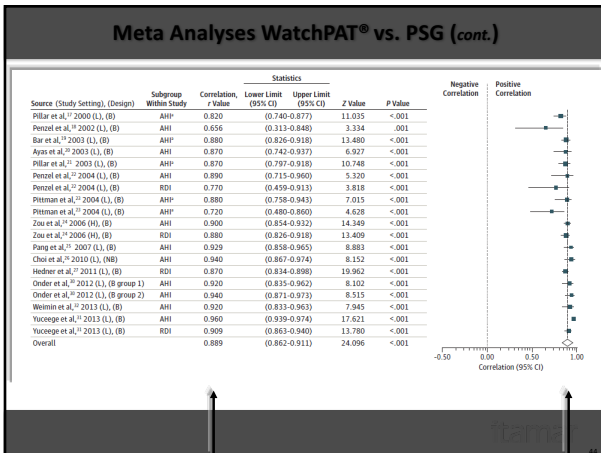
Original Investigation

Diagnosis of Obstructive Sleep Apnea by Peripheral Arterial Tonometry Meta-analysis

Sreeya Yalamanchali, MD; Viken Farajian, MS; Craig Hamilton, MBChB; Thomas R. Pott, MD; Christian G. Samuelson, MD; Michael Friedman, MD

JAMA Otolaryngol Head Neck Surg. doi:10.1001/jamaoto.2013.5338
Published online October 24, 2013.

Corresponding Author: Michael Friedman, MD, Department of Otolaryngology, Chicago ENT Advanced Center for Specialty Care, Advocate Illinois Masonic Medical



Sleep Stages Validation Papers

- Hedner J, Pillar G, Pittman S, Zou D, Grotte L, White D. A Novel adaptive wrist actigraphy algorithm for Sleep-Wake assessment in sleep apnea patients. *SLEEP* 2004; 27(8):1560-1566.
- Herscovici S, Pe'er A, Papyan S, Lavie P. Detecting REM sleep from the finger: automatic REM sleep algorithm based on Peripheral Arterial Tone (PAT) and actigraphy. *Physiol Meas* 2007; 28(2): 129-140.
- Bresler M, Sheffy K, Pillar G, Preiszler M, Herscovici S. Differentiating between light and deep sleep stages using an Ambulatory Device Based on Peripheral Arterial Tonometry. *Physiol Meas*. 2008; 29(5): 571-584.
- Hedner White DP, Malhotra A, Herscovici S, Pittman SD, Zou D, Grote L, Pillar G. Sleep staging based on autonomic signals: a multicenter validation study. *J Clin Sleep Med* 2011; 7:301-306.

Overall sleep stages agreement in the 70-80% range

Central vs. Obstructive Sleep Apnea Differentiation – a New WatchPAT capability

- PAT signal upstroke variations

- Respiratory movements (from SBP accelerometer)

Evaluation of the WP200U capability to identify central sleep apnea and Cheyne-Stokes Respiration , APSS 2016

T Penzel¹, D Hwang⁴, A Rama³, P Manthana^{4,5}, R Berry⁶, R Spiegel⁷, M Beral⁸, Marai Ibrahim⁹, Y Henkin¹⁰, R Tauman¹¹, G Pillar²

Post Modernism Era

Marilyn Diptych, Andy Warhol

“ This work can be conceived of as postmodern in many senses: its overt reference to popular culture/low art challenges the purity of the modernist aesthetic, its repetitive element is an homage to mass production.....”
from the Catalogue, Tate Modern, London

The Healthcare Post Modernism – the contemporary era

Creating postmodern health care

*People modernise health care in an attempt to absorb the effect of rising **need and demand resulting from demographic, technical, and social changes** that lie in the path of every health-care system. To cope, postmodern health will not only have to retain, and improve, the achievements of the modern era, but also respond to the priorities of postmodern society—namely: concern about the values as well as evidence; preoccupation with risk rather than benefit; **the rise of the well-informed patient.***

Muir Gray JA, THE LANCET • Vol 354 • October 30, 1999

Contemporary innovations – the Smartphone era

10 Things You Didn't Know You Can Do with Your Smartphone by Elizabeth Harper on September 08, 2016
in [Phone Accessories](#), [Phones and Mobile](#), [Mobile Apps](#), [Tips & How-Tos](#)

- Diagnose a leaky window
- Measure your heart health
- Prevent drunk driving
- See everything up close
- Measure your muscles
- Figure out why your check engine light is on
- Remind you to drink enough water
- Do some math (without a calculator)
- Improve your basketball skills
- Catch a fish

Definitely diagnose sleep in general and SDB in particular

SleepApps Search in Google



Android applications by Google Store. Accessed July 8, 2016
Free to 10 Euro

Fietze, Sleep Medicine Clinics 11: 461-468 (2016)

Smartphone Applications



How's My Sleep?



Sleepcycle to Wake

Motion sensing
Microphone
More sensors

Grifantini K. IEEE Pulse Magazine, Sept. 2014

Instructions



(a)

Stats



(b)

Sleep quality



(c)


FIGURE 1 Sleep Cycle uses the accelerometer in smartphones to detect movement. The app uses these readings to attempt to graph a user's sleep patterns. The screenshots show (a) the recommended placement of the smartphone, (b) the user's sleep statistics, and (c) sleep quality graphs. (Image courtesy of Sleep Cycle)

VitalPatch – small and disposable



<p>SENSOR</p> <ul style="list-style-type: none"> • ECG electrodes to detect heart rate • 3-axis MEMS accelerometer to detect motion • Thermistor to detect skin temperature <p>FORM FACTOR</p> <ul style="list-style-type: none"> • 11 g Adhesive Patch with integrated Sensor Module • 115 x 36 x 8 mm • Hydrocolloid adhesive 	<p>BATTERY</p> <ul style="list-style-type: none"> • Disposable zinc air battery • Battery life 96 hours (4 days) <p>REGULATORY COMPLIANCE</p> <ul style="list-style-type: none"> • FDA cleared • CE Marked • ISO 13485 certified • CDRR registered
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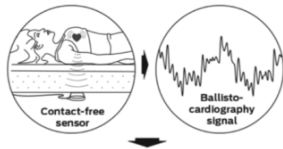
Somnarus Patch




Air flow
 Heart rate
 Respiratory effort
 Blood oxygen
 Body position
 Sleep

Emfit QS


Ballistocardiography- (BCG) is a measure of ballistic forces on the heart generated by the ejection of blood into the big vessels by each heart beat. Emfit – Electromechanical film transducer




Sleep monitoring analyzed by heart rate variability. All parameters measured by a sensor under the mattress, including heart rate, breathing rate, movement activity and all sleep classes.




Under mattress sleep tracker



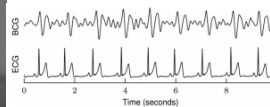
Full night Heart-Rate-Variability




Three sleep classes (REM, Deep & Light)



Heart & breathing rate



Beddit – taking the Smart Sheet to the Smartphone



Dimensions	Sensor 80 × 8 × 0.15 cm / 31.5 × 3.1 × 0.06 inch Cable 3 meters / 10 feet	Sleep Measurements	Sleep time Sleep efficiency Time to fall asleep Restless sleep Sleep cycles Light/Deep sleep Bedtime Wake-up time Away from bed Awake in bed Sleep score	Breathing Measurements	Average breathing rate
Sensors	Flex force sensor Capacitive touch sensor Humidity sensor Temperature sensor Microphone (in the smartphone)	Snoring Measurements	Snoring events Total duration of snoring	Mobile App	Smart alarm Results (Stats & graph) Notes (Feelings & tags) - iOS only Trends (7, 30, 90 days) - iOS only

Beddit – As from May an Apple product

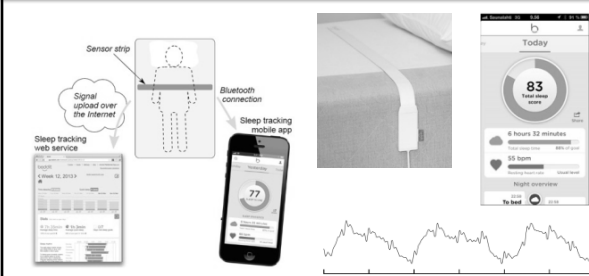
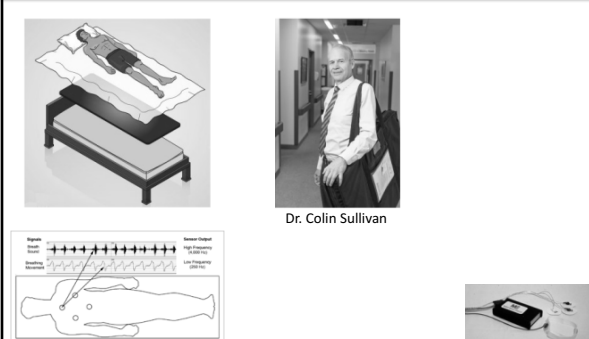


Figure 2. Overview of the sleep measurement system. Vibrations of the body are measured with a force sensor placed under the body in the bed. The signals are analyzed at a web service or smartphone app and presented to the user.

*Paalasmaa J, Toivonen H, Partinen M: Adaptive Heartbeat Modeling for Beat-to-Beat Heart Rate Measurement in Ballistocardiograms
IEEE JBHI 19:1945-1952 (2015)*

The Sonomat – vibration & acoustic sensors



Dr. Colin Sullivan

BresoDx – Acoustic and Movement



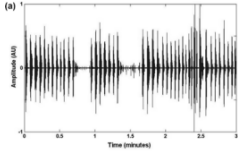
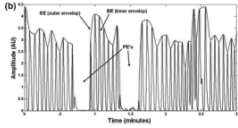


Fig. (5). Acoustic portable monitor, BresoDx™ which uses a microphone placed in front of nose and mouth embedded in a flanged structure devised at the Toronto Rehabilitation Institute, UHN, Canada.




Dr. Doug Bradley


Alshaer H *et al* , Sleep medicine 2016

ResMed behind - S+




- The S+ measures movements using ultra low power radio waves
- noncontact sensing of respiration pattern
- reports REM and NREM sleep stages based on stage-specific breathing patterns

Non medical grade - and yet ResMed



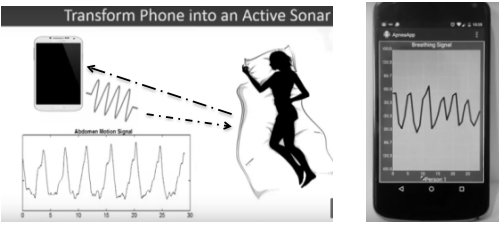
Nokia behind - Withings Aura Sleep System



Light waves
Acoustic Waves
Sleep and respiration analysis


ApneaApp

Transform Phone into an Active Sonar



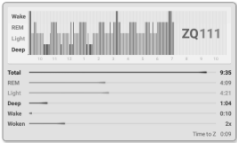
A collaboration between UW and Oxford

The Zeo adventure



Features:

- New EEG/EOG electrodes technology
- Sophisticated neural network expert system
- Sleep quality
- Self-training using artificial intelligence



The Zeo adventure



- The hottest names in sleep research
- The hottest names in bio-medical business
- Investigators were queuing



Consumer sleep monitors: is there a baby in the bathwater? K Russo et al, Nat Sci Sleep 2015

The rapid expansion of consumer sleep devices is outpacing the validation data necessary to assess the potential use of these devices in clinical and research settings

To place the marketing trends and demand into perspective, we note that a consumer sleep monitor with no published validation was listed among Time Magazine's inventions of the year in 2005

The more widely these products enjoy consumption, the more urgently important it is for all stakeholders to engage in resolving the current state of claim validation mismatch

So where does it take us? Up or Down?

<p>Opportunities</p> <ul style="list-style-type: none"> New exciting technologies Involvement of "supper powers" – resources Consumer market – expand awareness to sleep 		<p>Risks</p> <ul style="list-style-type: none"> Lack of pivotal validation Involvement of "Supper powers" – bias of economical interest Consumer market – consumers control of medical procedures
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Up or Down?


In other words

Optimistic?

Pessimistic?

Probably something in between

The Optimistic....
Emile Habibi, 1984





האופטימיסט
המשחין

אתל חיבי
האופטימסט


הוצאת הוצאת
על ידי
סדר על ידי

תל אביב


Many Thanks to Colleagues



Dr. Peretz Iavie



Dr. Bob Schnall



Late Dr. Daniel Goor

תל אביב
