Obstructive Sleep Apnea Detection with Consumer Electronics?

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Outlook:

- Motivation & goals of the CESAR Project
    - what is OSA
    - how is OSA diagnosed
    - how CESAR aims to contribute

- 1st step towards non-intrusive OSA event detection
    - signal types
    - data mining techniques
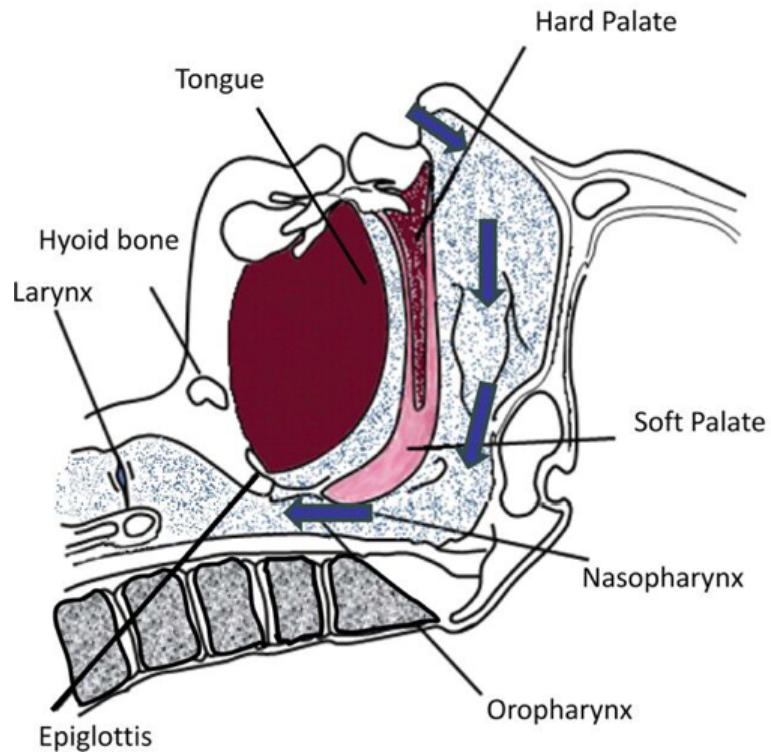   - data sets and data preparation
    - results

- Discussion

Disclaimer:

- no fancy .ppt show today
- missing references to the origin of the pictures used

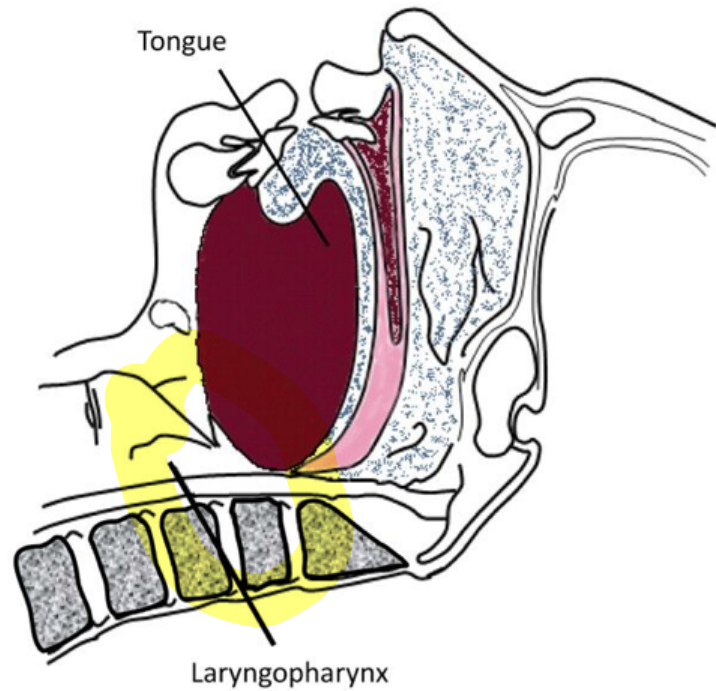- no new data mining - just the application of vanilla configurations in MatLab (we are still learning.......)

What is OSA?

Obstructive Sleep Apnea

Upper airway anatomy

Sites of obstruction during sleep apnea

Hard Palate

Tongue

Hyoid bone

Larynx

Soft Palate

Nasopharynx

Oropharynx

Epiglottis

Tongue

Laryngopharynx

The Consequences of
Obstructive Sleep Apnea

Obstructive sleep apnea afflicts 1 in every 5 Americans.
What other problems arise for OSA patients?

90%

STROKE
» Men with moderate to severe OSA were nearly 3x more likely to have a stroke.
» OSA is often found in patients following a stroke.
» Risk of stroke rises with severity of the disease.

STRESS ON THE HEART

77%

HYPERTENSION
» Sleep apnea is an identifiable cause of high blood pressure.
» OSA is the leading cause of secondary hypertension.

25%

CORONARY ARTERY DISEASE

58%

CARDIAC ARRHYTHMIAS
» 4x as likely to have atrial fibrillation

76%

CONGESTIVE HEART FAILURE
» Moderate OSA have increased mortality rates.
» New patients are screened for OSA.

38%

HEART DISEASE

30%

SUDDEN DEATH
» OSA sufferers have a 30% higher risk of heart attack or premature death.

More than 50% of sudden deaths from OSA occur between 10 pm and 6 am.

MEDICAL COSTS
» Untreated sleep apnea costs Americans an extra 4.3 billion per year.
» Treated sleep apnea can halve a patient's healthcare costs.

Change in annual health care costs per patient after treating OSA

$200,000

aviisha®
Medical Institute, LLC

POOR SLEEP*
58% | **87%**

MOOD DISTURBANCE
» Depression
» Anxiety
» Loss of motivation
» Shortened attention span
» Moodiness and bad temper
» Poorer judgment

DAYTIME SLEEPINESS
» 6-fold increased risk of car accidents
» Impaired concentration and memory loss
» Reduced work-efficiency
» Reduced alertness
» Slower reaction time

80%

LOUD SNORING
» Relationship discord
» Morning headaches caused by oxygen deprivation

15%

DIABETES TYPE II
» Lack of insulin control and poorly controlled blood sugars
» 58% have OSA

OBESITY
» As sleep shortens or diminishes in quality, appetite for high-calorie food increases.
» Obesity is the best documented risk factor for OSA. It is estimated that 90% of obese males and 50% of obese females have OSA.
» The prevalence of OSA increases with body mass index (BMI).
» Approximately 80% of OSA patients weigh 130% or more of their ideal body weight.

61%

60%

GASTROESOPHAGEAL REFLUX DISEASE (GERD)

80%
of middle-aged men

SEXUAL DYSFUNCTION
» Loss of libido
» Impotence

48%

NOCTURIA
» Frequent urination at night

* Many patients may not be aware of their poor sleep quality.

How is OSA diagnosed?

A

Sensor at nose to measure air flow

Sensors on face and scalp measure eye movement and brain activity

Wires transmit data to a computer. A technician in a nearby room monitors the data.

Elastic belt sensors around chest and belly measure amount of effort to breath

Sensor on finger measures amount of oxygen in blood
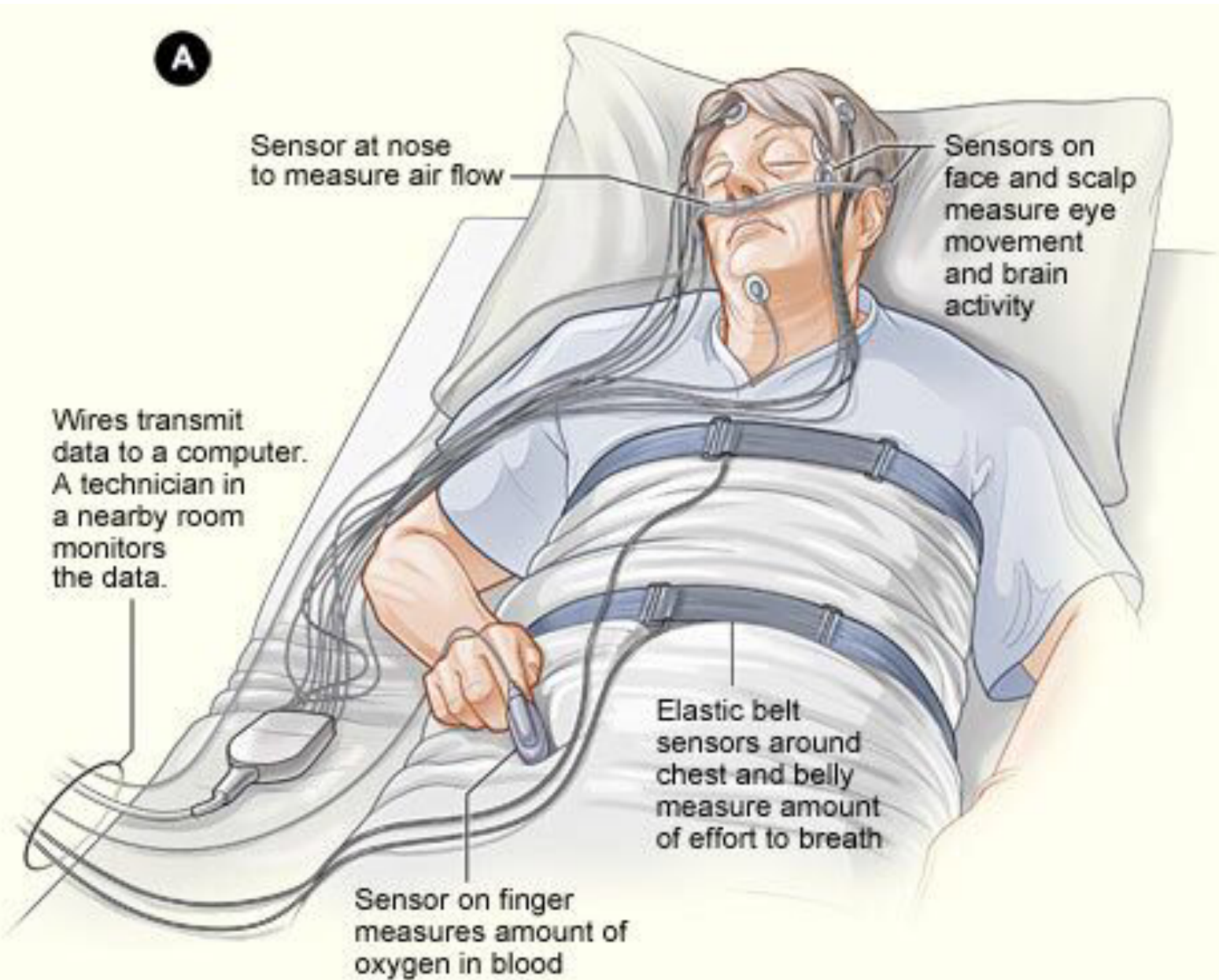
Polysomnography (PSG)
the gold standard

Mobile
PSG
from
Nox medical
Nox T3
price
> 7000 €
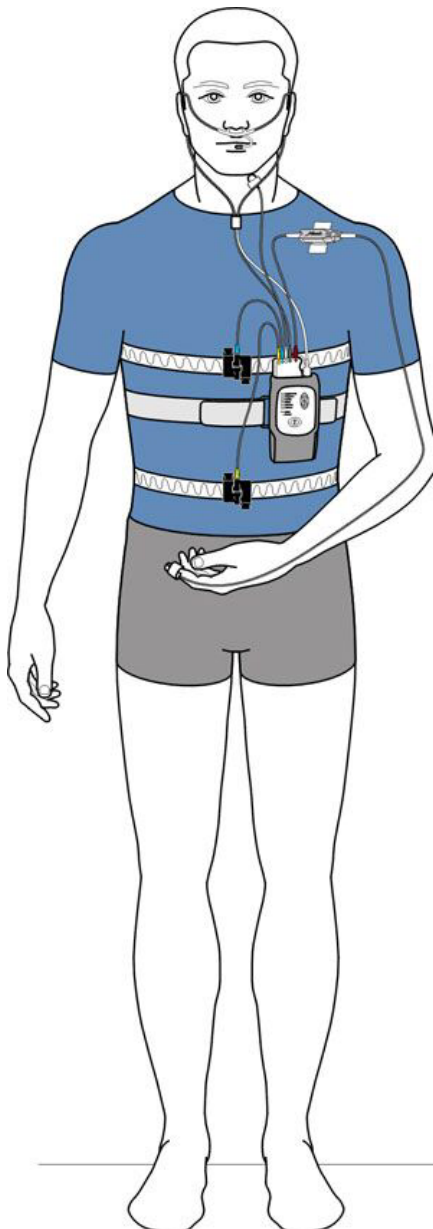
How is OSA diagnosed? (cont.)

Normal Polysomnograph

electro encephalogram

EEG

electromyo gram

EMG

electro cardio gram

ECG

arterial blood Preasure

BP

Abdomen

Abd

Chest

Vt (air flow)

100

Pulse Oxygen Saturation

75

20 sec   Time (minutes)

Obstructive Sleep Apnea

EEG
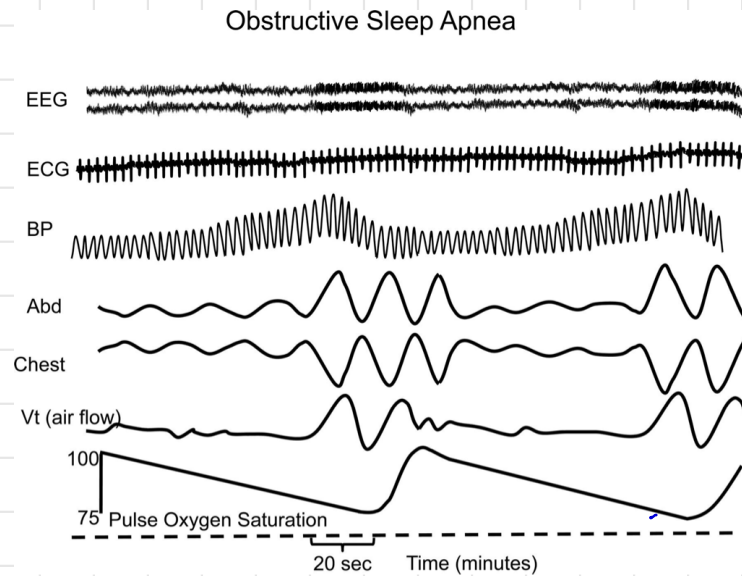
ECG

BP

Abd

Chest

Vt (air flow)

100

75 Pulse Oxygen Saturation

20 sec   Time (minutes)

M. Levitsky "Using the pathophysiology of OSA to teach cardiopulmonary integration" 2008

How is OSA diagnosed? (cont.)

Obstructive Sleep Apnea

EEG

ECG

BP

Abd

Chest

Vt (air flow)

100

75 Pulse Oxygen Saturation

20 sec   Time (minutes)

- trained personall inspects the monitored data

- identifies apnea events (breathing pause & reduced oxygen saturation of 10s and more)

- Apnea-Hypopnea Index (AHI) defines severity of OSA (# apnea events per hour), $t \geq 10\ seconds$

Normal: AHI<5
Mild sleep apnea: 5≤AHI<15
Moderate sleep apnea: 15≤AHI<30
Severe sleep apnea: AHI≥30

CESAR: Using Complex Event Processing for Low-threshold and Non-intrusive Sleep Apnea Monitoring at Home

Vera Goebel, Sigurd Aarrestad, Harriet Akre, Mohan Kankanhalli, Stein Kristiansen, Thomas Plagemann

Smartphones & sensors for physiological signals are available & "cheap"

Examples: BiTalino, Cooking Hacks Shimmer
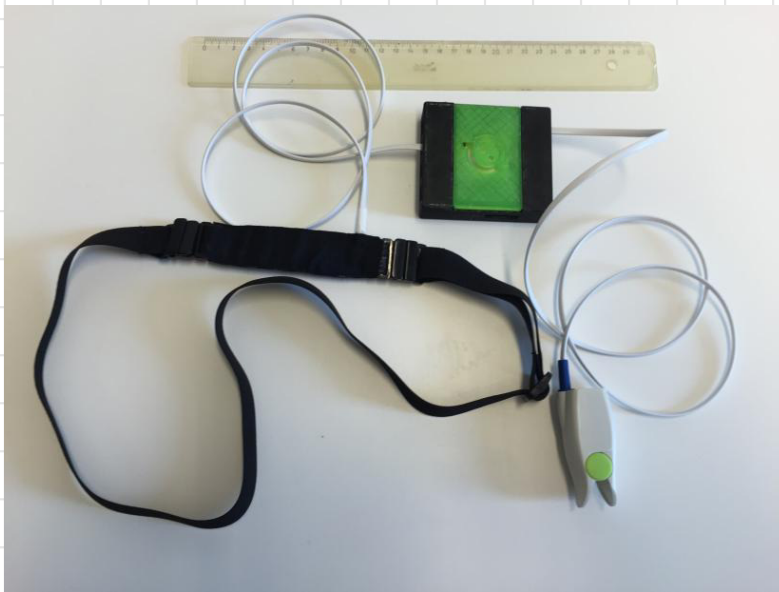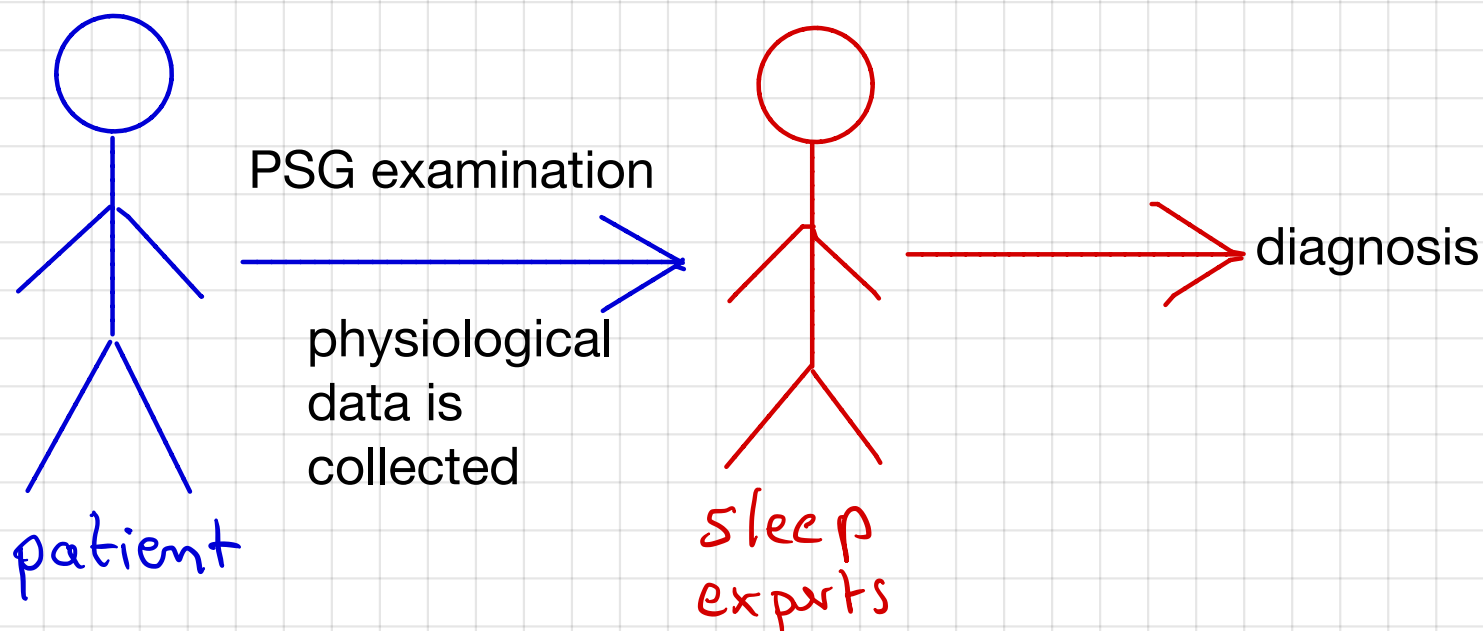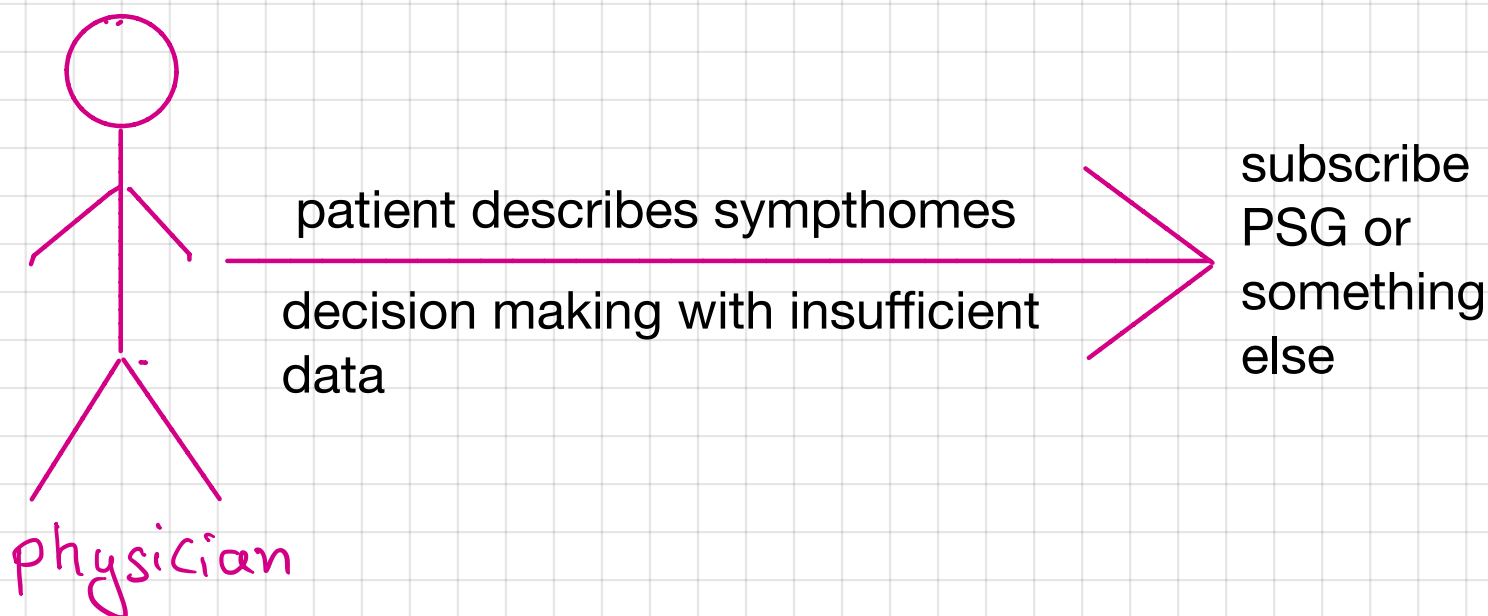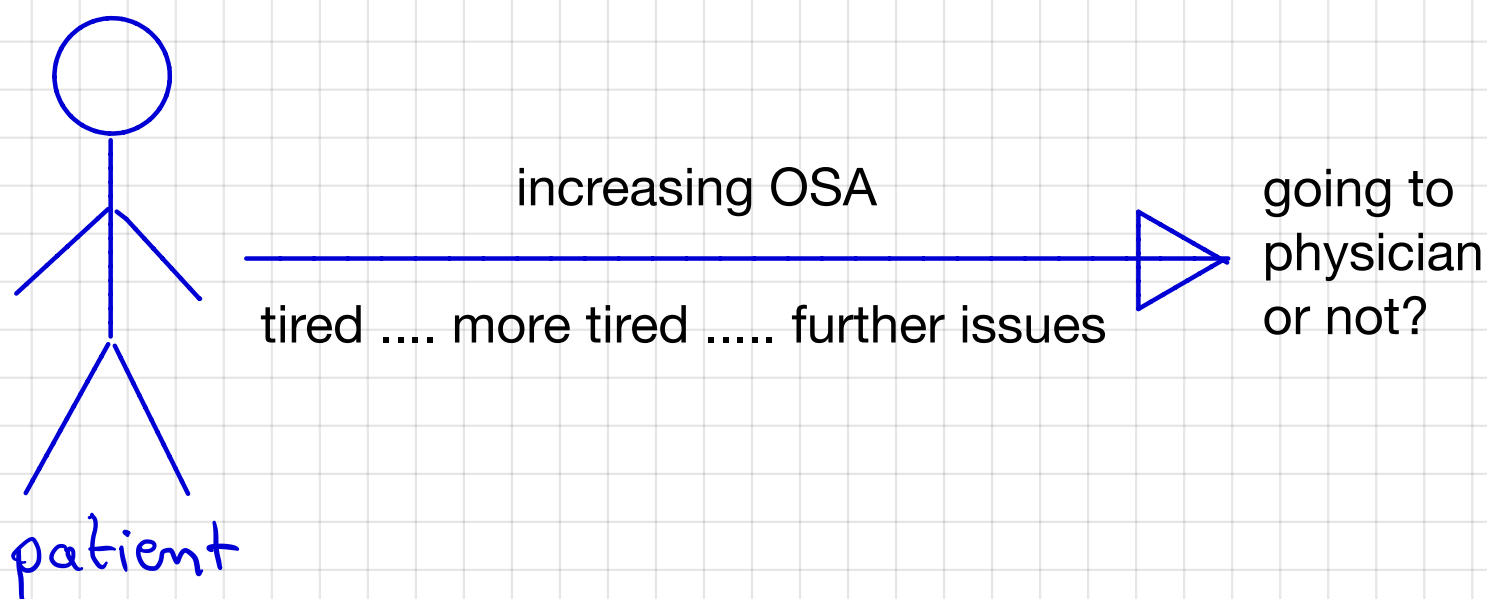
How far can we go
with these cheap sensor
sets to support OSA diagnosis?

⟶ HW   performance
             reliability

⟶ SW   signal processing
             data mining

⟶ Users   Placement of
               sensors

Three steps of OSA diagnosis

patient

increasing OSA

tired .... more tired ..... further issues

going to physician or not?

---

physician

patient describes symphomes

decision making with insufficient data

subscribe PSG or something else

---

patient

PSG examination

physiological data is collected

sleep experts

diagnosis

Let's envision:

- we could develop an extensible app
- that can with one easy to use sensor get some data that could indicate whether OSA might be an issue

 ⟹ the user could buy additional sensors to get more data for OSA event detection

  ⟹ the user/patient could show the MD the data

  ⟹ the MD has now a good set of data to decide whether a PSG should be done

Building Blocks of Possible MSc Theses in CESAR

- Machine learning for OSA detection
- Real-time data quality analysis:
  - Complex Event Processing
  - Machine learning
  - Other means …..
- Tools for data collection and import of data from external sources
- Building a data set ->
- Building an extensible App ->

Building a Data Set

Shared Database
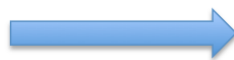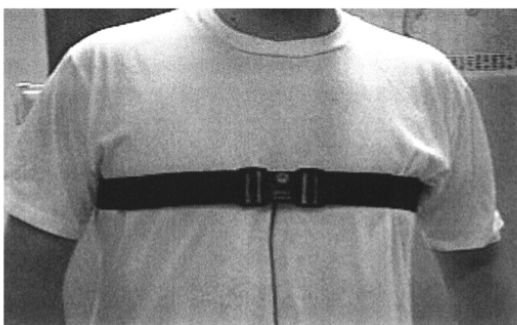
Different
- Signal types
- Sensor brands
- Breathing patterns
- Sleeping positions
- Placement on body
- Other environmental factors

[Source of picture: http://ttktamop.elte.hu/online-tananyagok/physiology_practical/ch13s02.html]
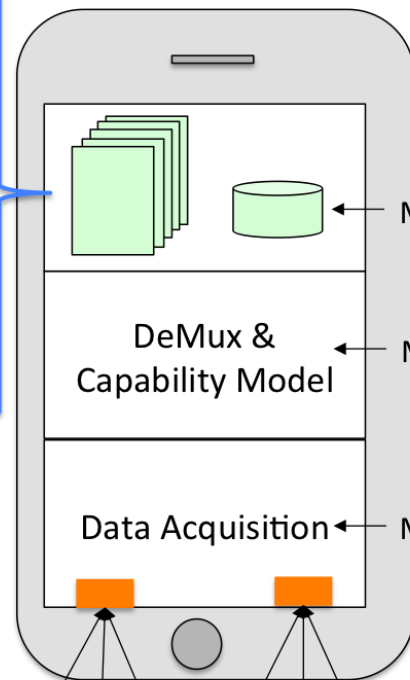
Building an extensible APP

New thesis topics:

New modules for
- Visualization
- Data analytics
- User support
- Report generation

Integration based on MVC principels

MSc Thesis from Viet Thi Nguyen

Daniel Bugajski Przemyslaw
MSc Thesis from Svein Petter Gjøby

DeMux & Capability Model

Data Acquisition ← MSc Thesis from Svein Petter Gjøby

BiTalino   Shimmer

What are the immediate research questions to be answered?

- which signal types are "needed"
  - easy to use
  - comfortable for the user
  - cheap
  - "good" for OSA event detection
- can data mining be used to automatically detect OSA events
  - which is best ANN, KNN, SVM, DT, ... ?
  - what are the computational costs (can it be used on smart phones)?