



**THE INTERNET OF HEALTH:**  
WIRELESS SENSORS FOR PREVENTION, CURE AND CARE

CHRIS VAN HOOFF – senior director personal health solutions, imec  
imec Fellow, professor KU Leuven



50%



33%



10%





**COPD**

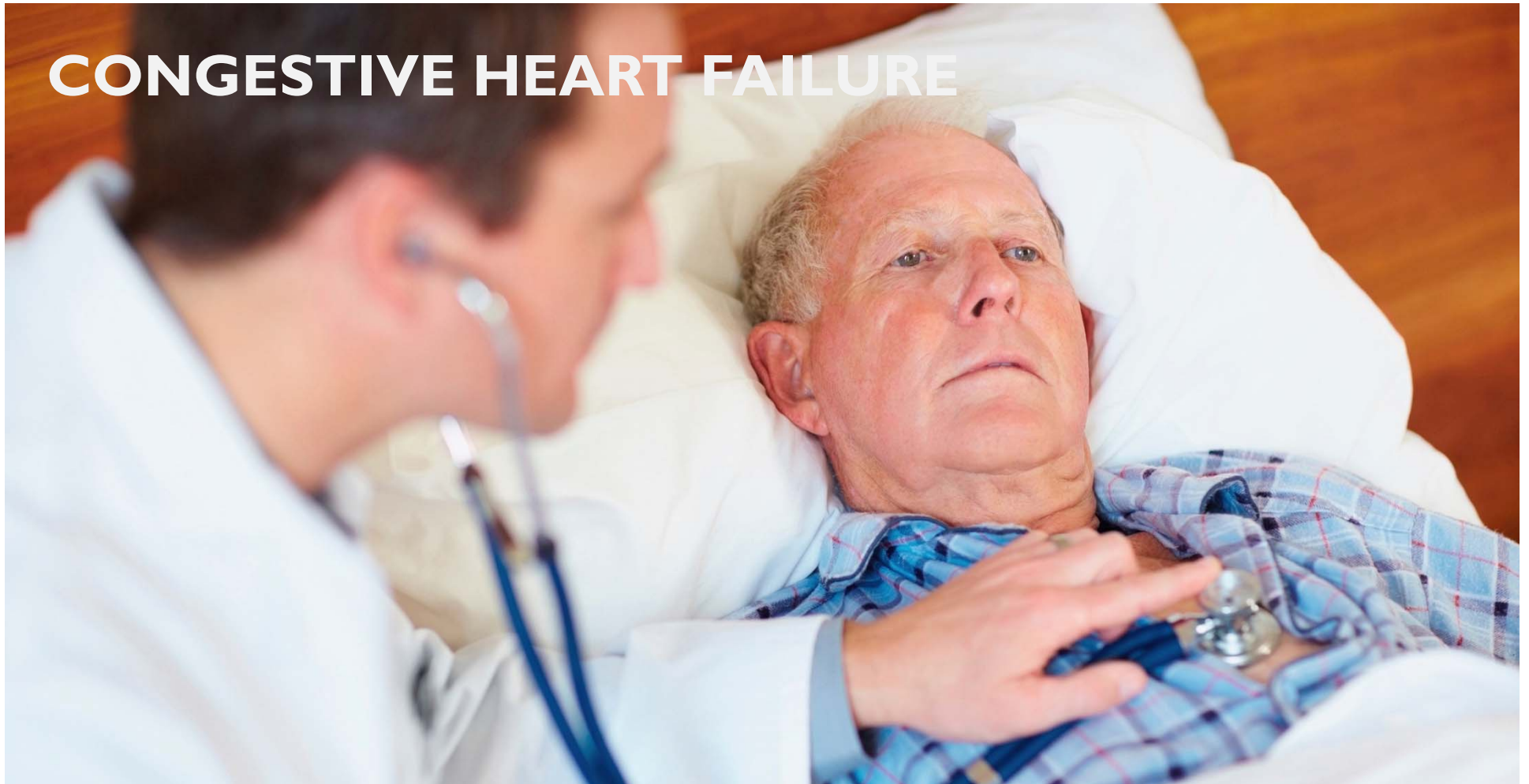
**174 MILLION PATIENTS WORLDWIDE ; LIMITED REMOTE TOOLS TO DETECT EXACERBATIONS**

# SLEEP APNEA



> 100 MILLION PATIENTS WORLDWIDE ; LIMITED REMOTE DIAGNOSTIC TOOLS

# CONGESTIVE HEART FAILURE



26 MILLION PATIENTS GLOBALLY ; NO REMOTE TOOLS FOR CONGESTION MONITORING

# HYPERTENSION

A photograph of an elderly man and woman sitting at a table in a rustic setting. The woman is wearing a green sweater and has a blood pressure cuff on her left arm. She is holding a silver blood pressure monitor. The man, wearing a blue and yellow striped polo shirt, is looking at her with a thoughtful expression, his hand resting on his chin. The table is covered with a white lace tablecloth and has a glass of water on it. In the background, there is a stone fireplace and a window with greenery outside.

78 MILLION ADULTS WITH HYPERTENSION IN US ALONE ; 12% CHANGES HIS/HER LIFESTYLE

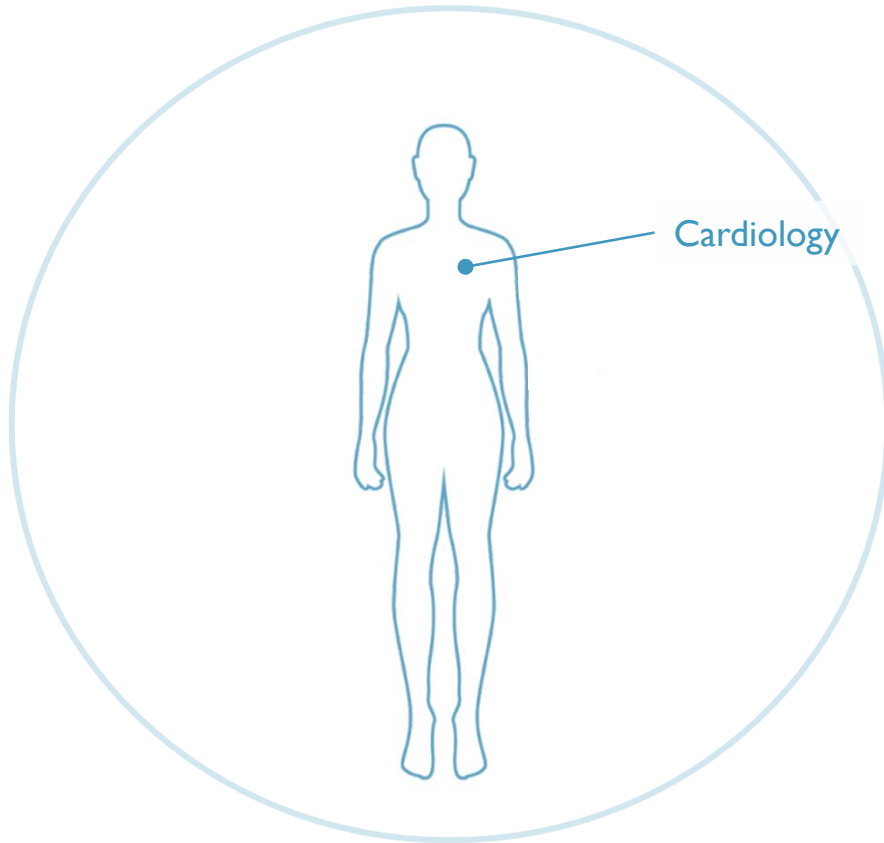




NEW  
MEDICAL  
DIAGNOSTIC  
TOOLS  
ARE  
NEEDED  
FOR  
**DAILY**  
USE  
AT  
**HOME**

# WEARABLE & PERSONAL HEALTH MONITORING

## APPLICATION DOMAIN – **CARDIOLOGY - HYPERTENSION**



# TRACK RECORD: SIMBAND PLATFORM

WEARABLE PLATFORM WITH IMEC CIRCUITS & APPLICATION ALGORITHMS INSIDE



Circuit  
&  
System  
R&D

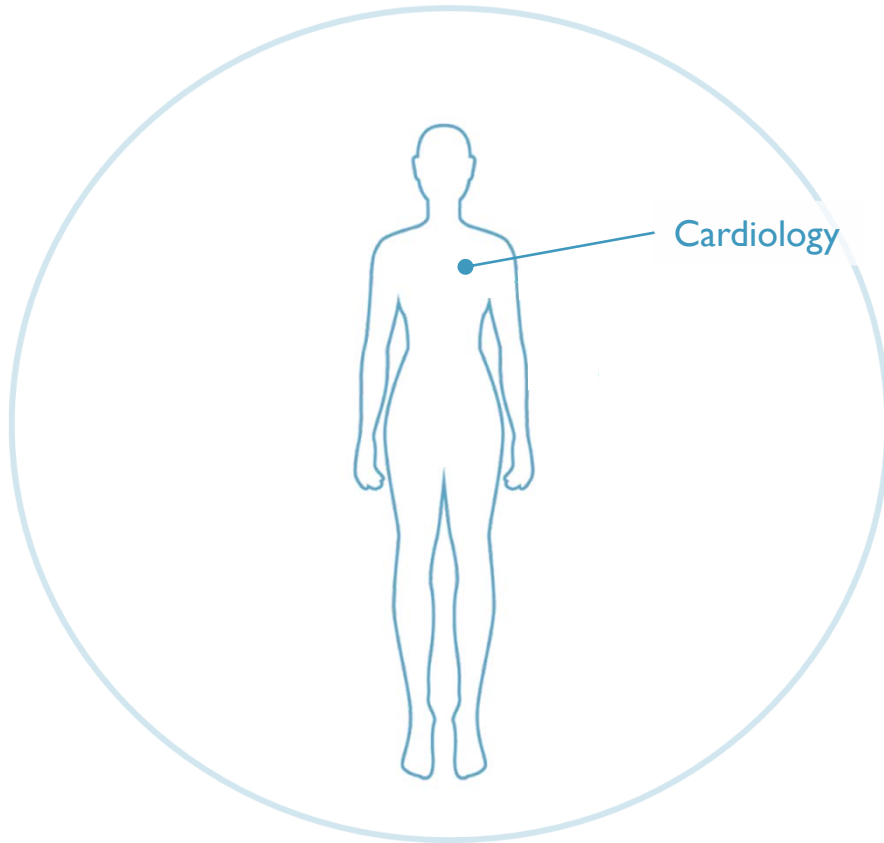
System  
DoD

System  
DoD

System  
DoD

Application  
DoD

# WEARABLE & PERSONAL HEALTH MONITORING APPLICATION DOMAIN – **CARDIOLOGY**



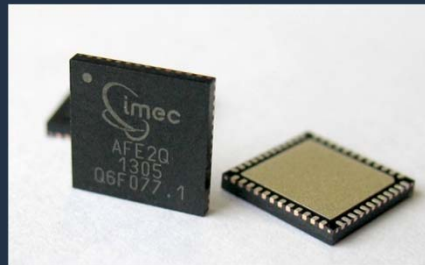
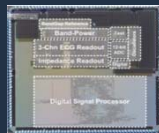
BioTelemetry<sup>inc.</sup>



# TRACK RECORD: CARDIAC MONITOR FDA APPROVED

WEARABLE MEDICAL **SYSTEM** DESIGNED BY IMEC AND WITH IMEC **CIRCUITS** INSIDE

BioTelemetry  
inc.



Wireless  
Mobile  
Cardiac  
Outpatient  
Telemetry  
Device

Circuit  
R&D

Circuit  
R&D

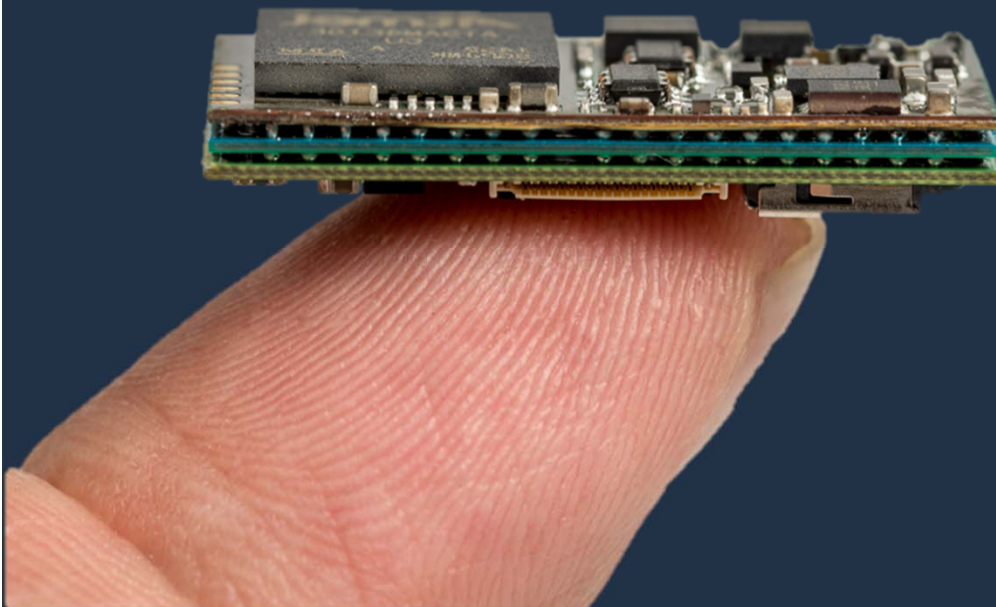
System  
R&D

Qualify  
Circuit  
&  
System

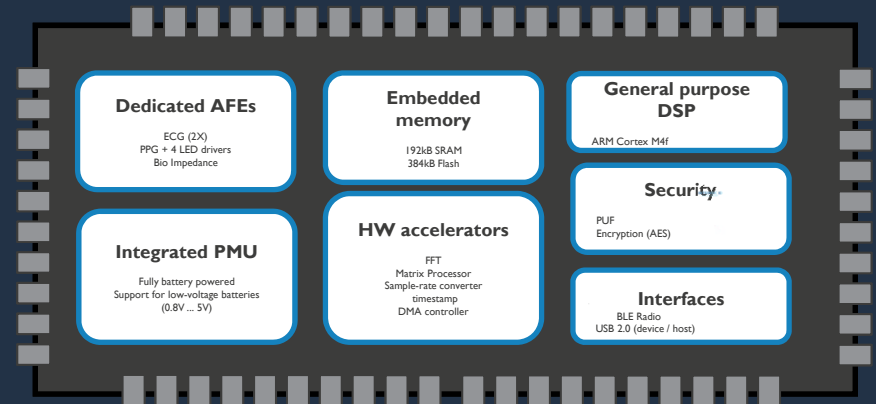
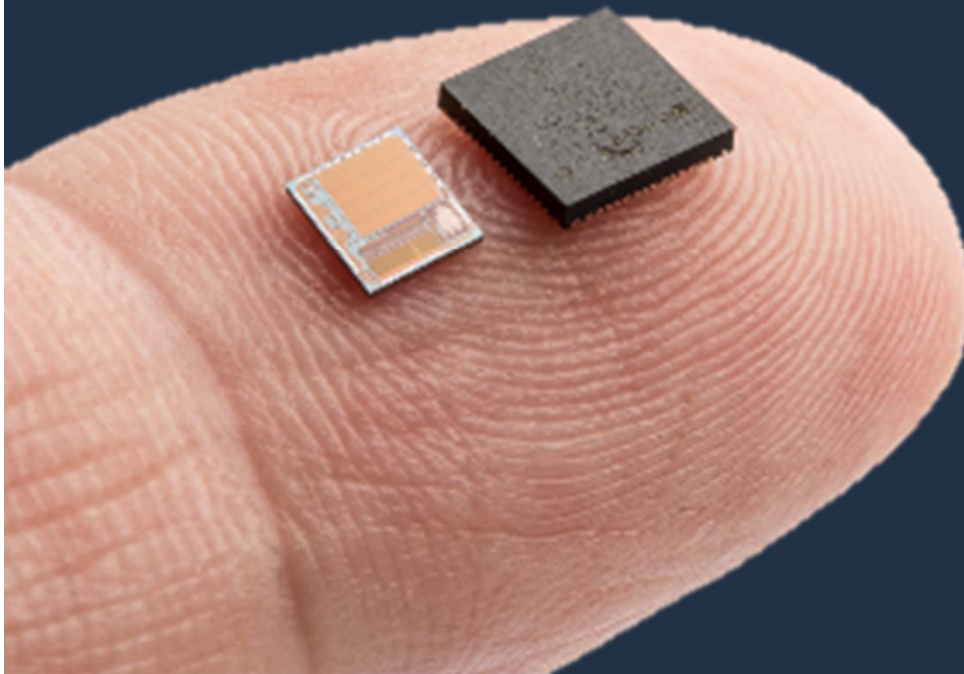


July 2016

**MINIATURIZATION  
=  
COST REDUCTION**

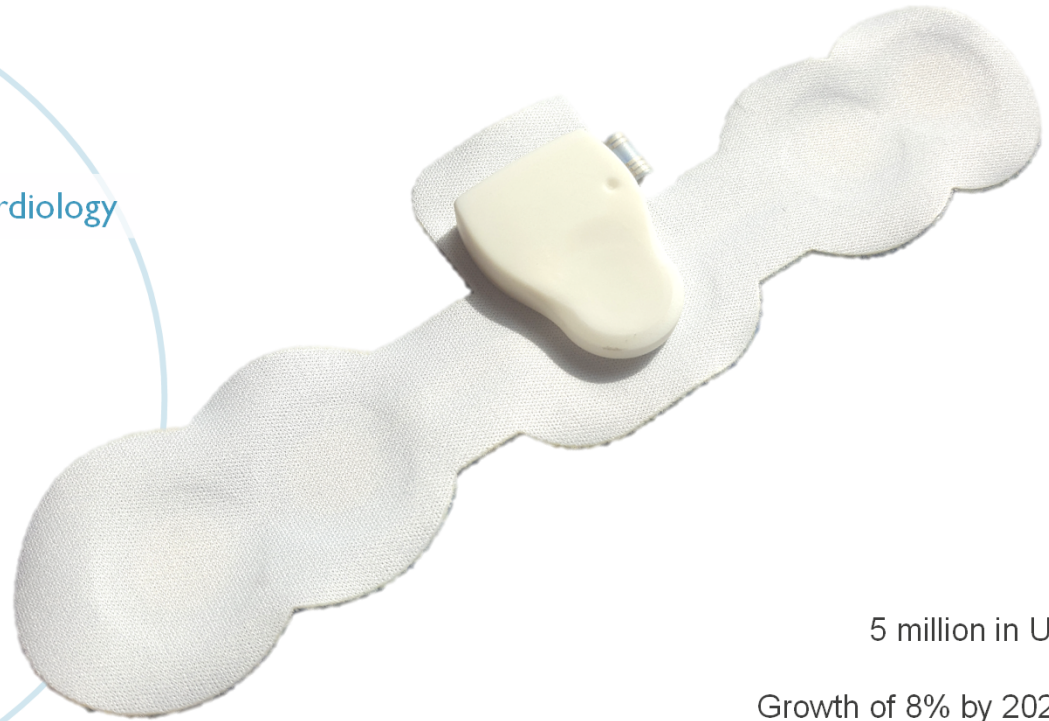
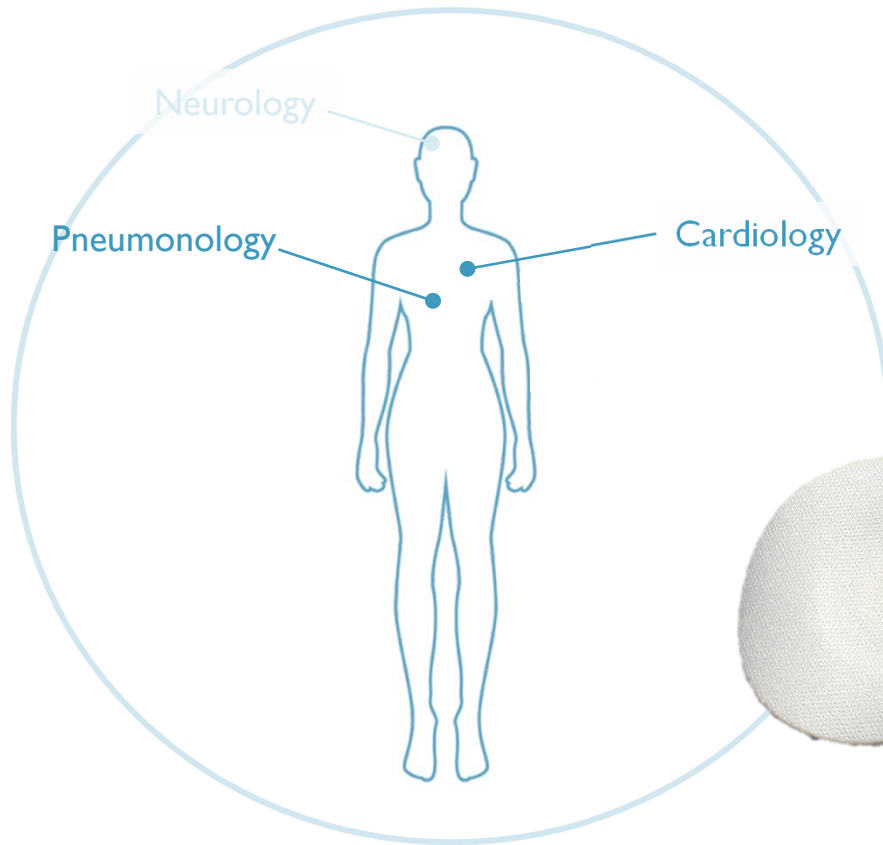


# THE FUTURE: A SINGLE-CHIP VITAL SIGN MONITOR



# WEARABLE & PERSONAL HEALTH MONITORING

## APPLICATION DOMAIN **CARDIO-PULMONARY DISORDERS: CHF**



5 million in US

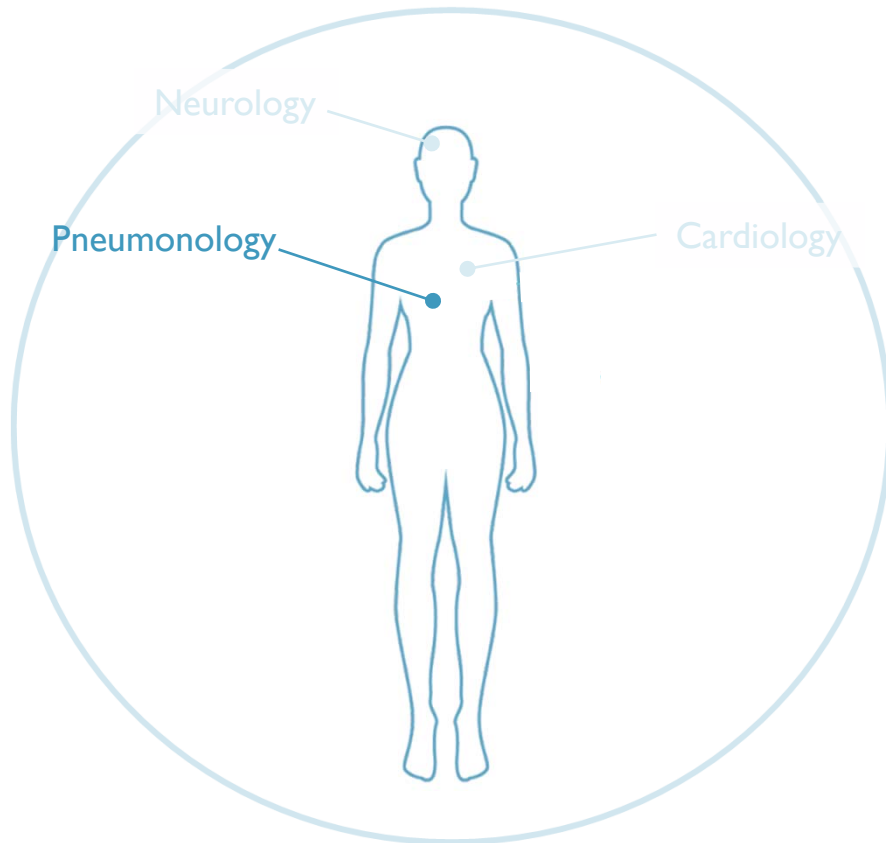
Growth of 8% by 2025

Goal: Prevent or reduce hospital readmissions



# WEARABLE & PERSONAL HEALTH MONITORING

## APPLICATION DOMAIN **PNEUMONOLOGY**: OSA AND COPD



### **OSA**

19 million UNDIAGNOSED in US

Goal: Improve ease of diagnosis

### **COPD**

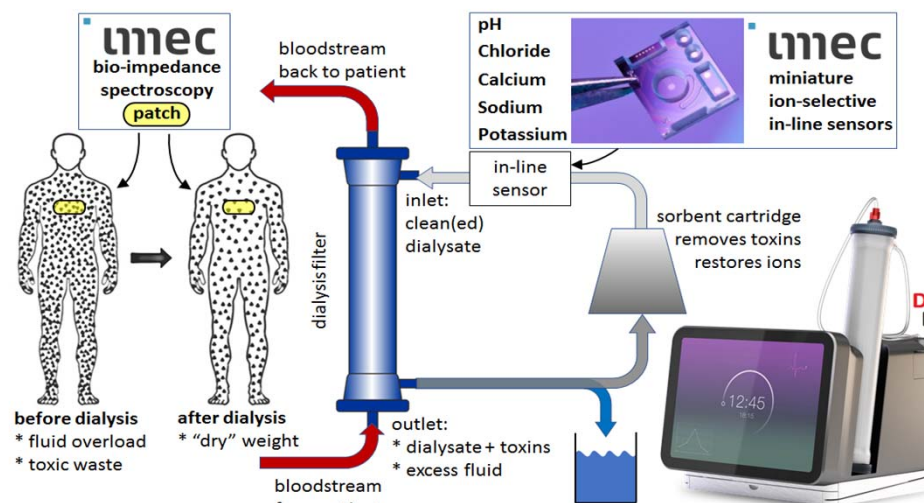
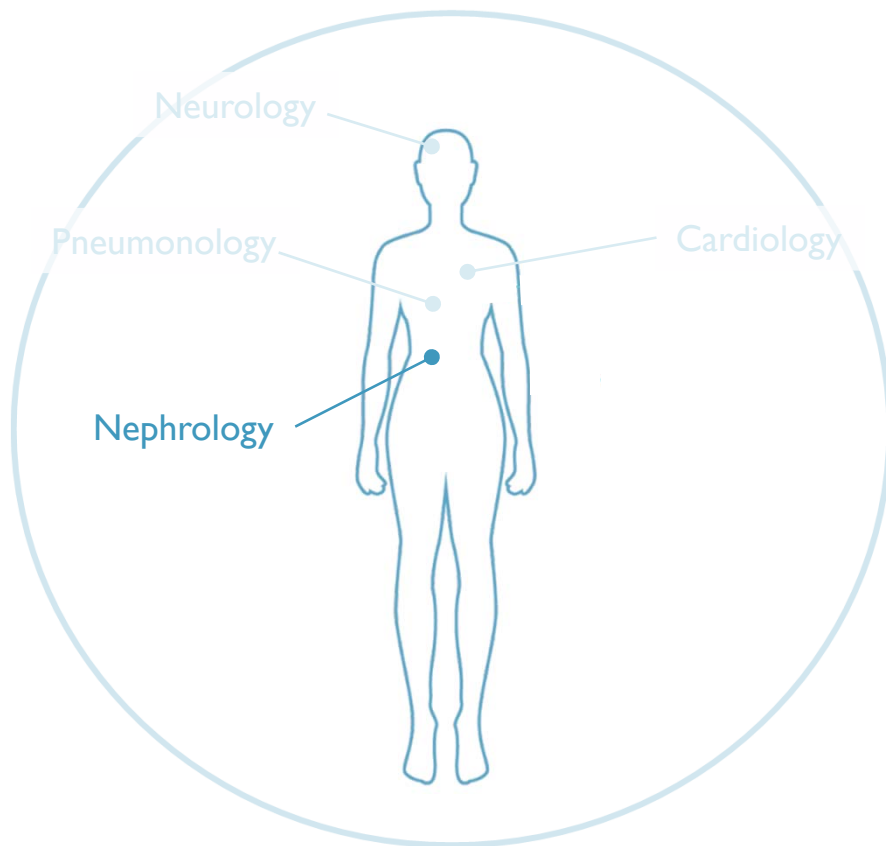
15 million in US

Growth of 16% by 2025

Goal: Prevent exacerbations and coach towards an active lifestyle

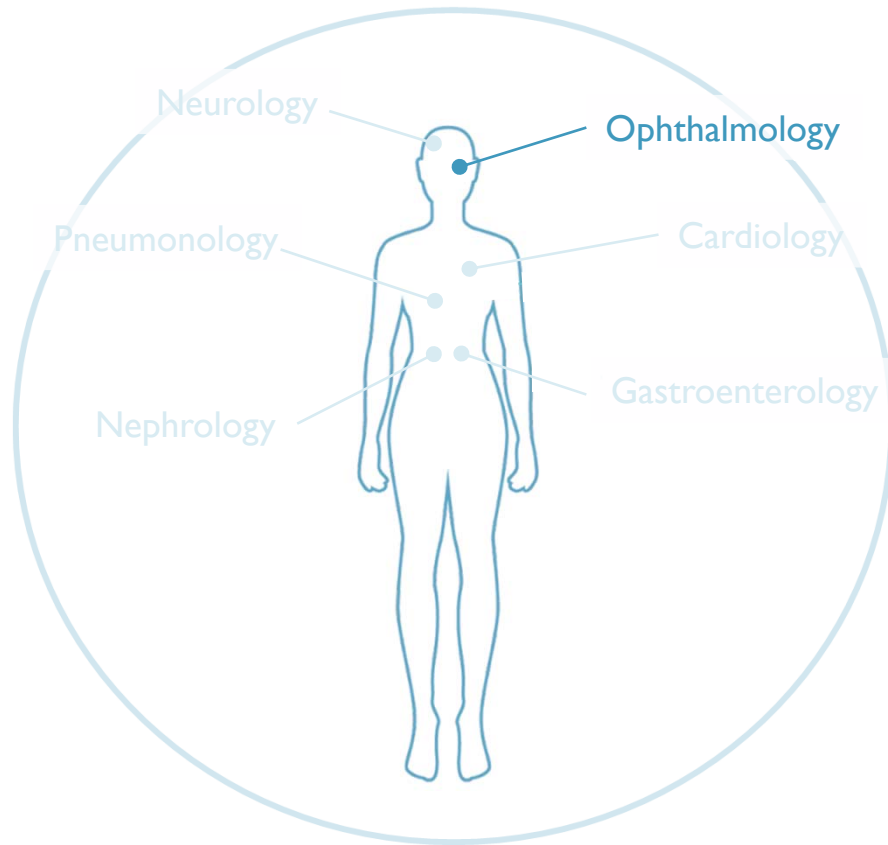
# WEARABLE & PERSONAL HEALTH MONITORING

## APPLICATION DOMAIN **NEPHROLOGY**: CKD

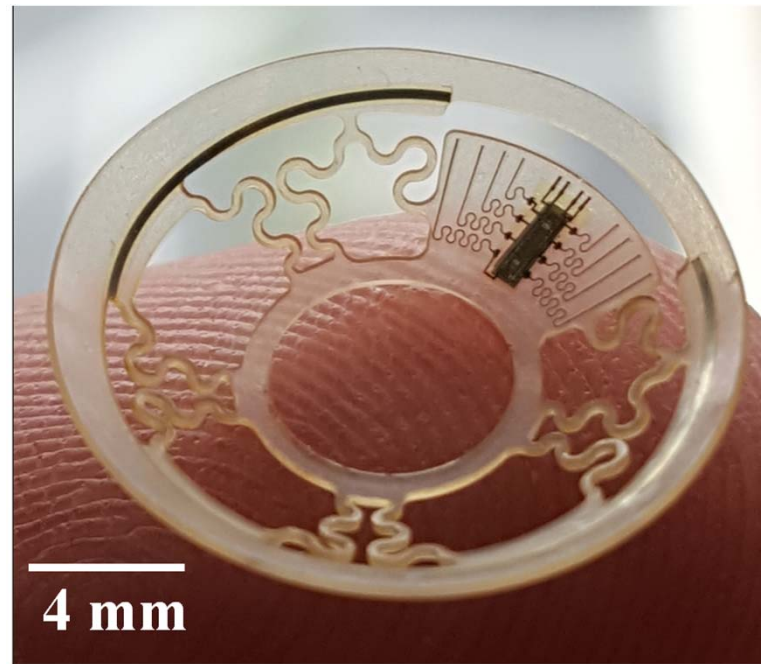


# WEARABLE & PERSONAL HEALTH MONITORING

## APPLICATION DOMAIN **OPHTHALMOLOGY**: SMART CONTACT LENSES



2017-2018 exploration of multiple diopeters & autofocus



# THE ESSENTIAL ROLE OF CLINICAL PARTNERS



SUCH DIGITAL HEALTH DEVICES NEED TO PUT THROUGH EXTENSIVE CLINICAL RESEARCH STUDIES



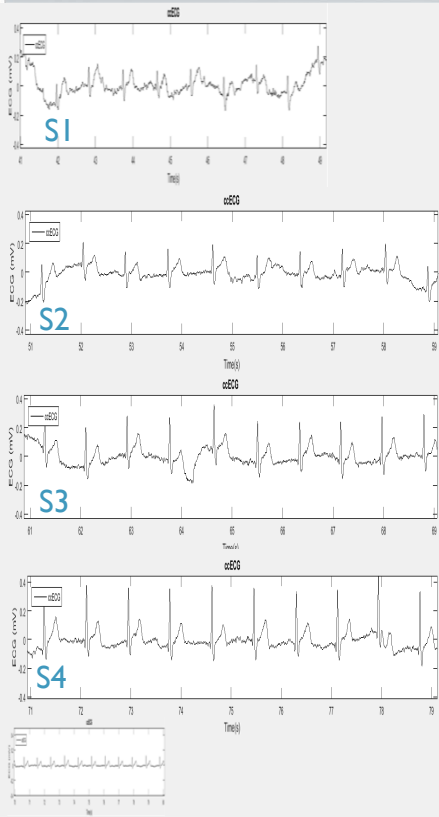
TODAY, SUCH WEARABLE HEALTH  
MONITORING DEVICES ARE BECOMING  
IDEALLY SUITED FOR CHRONIC DISEASE  
DIAGNOSIS & FOLLOW-UP ...

... ESPECIALLY WHEN LONGITUDINAL RECORDING IS NEEDED

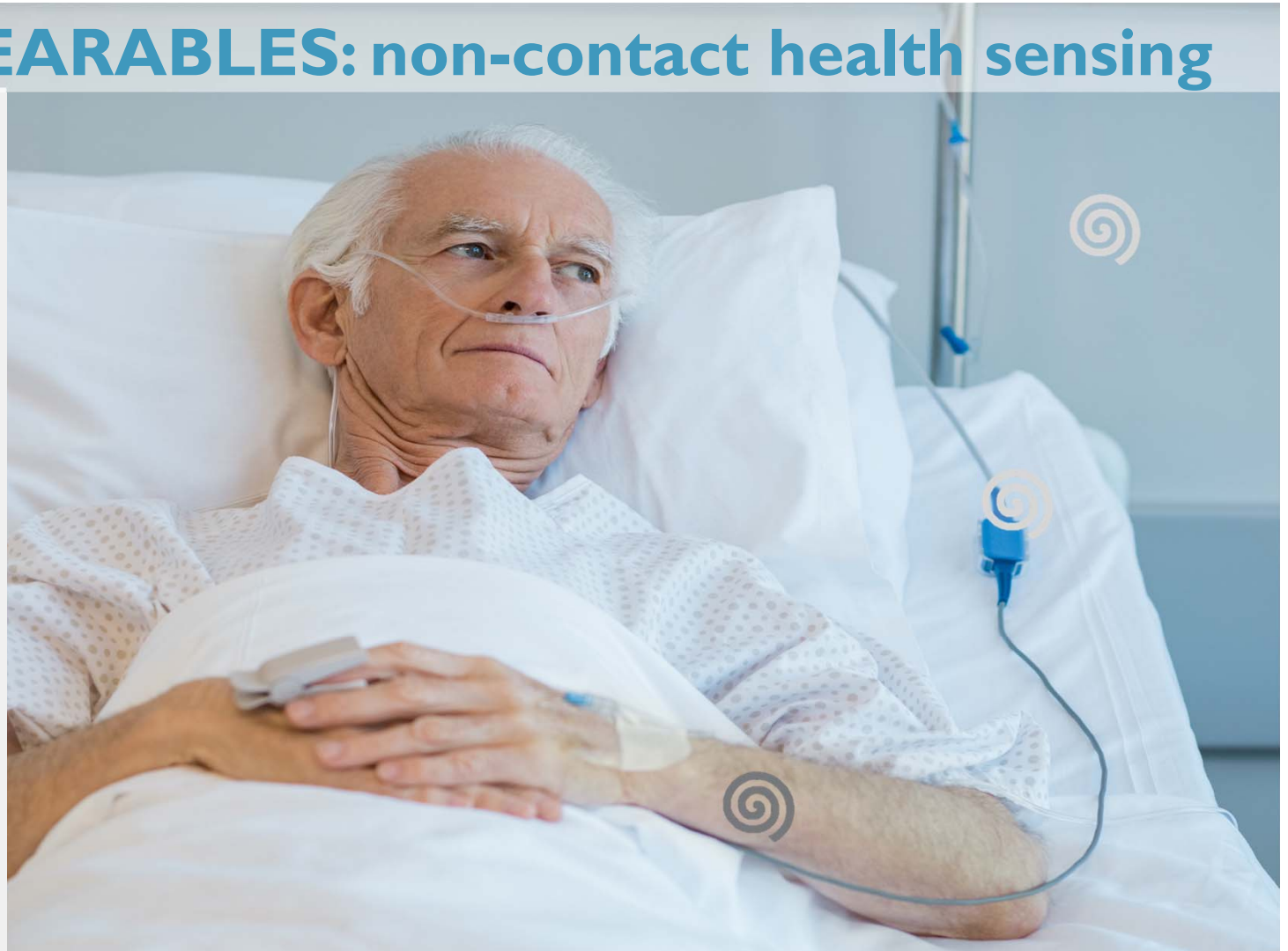
# BEYOND WEARABLES: NON-CONTACT SENSING



# BEYOND WEARABLES: non-contact health sensing

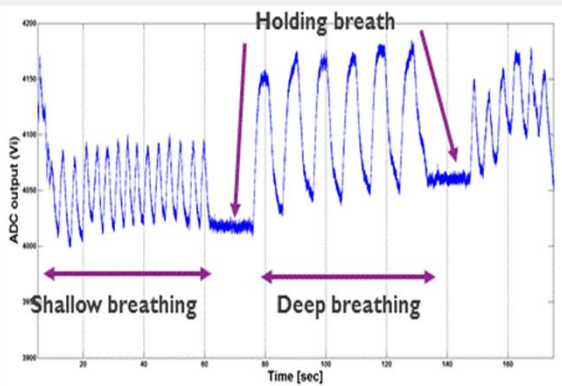
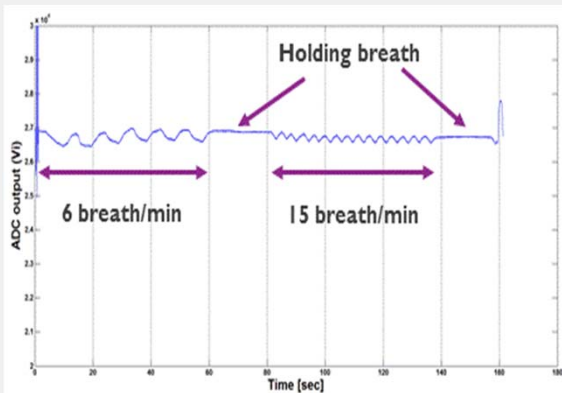


**Multi-location capacitive  
ECG sensing  
through bed linen**





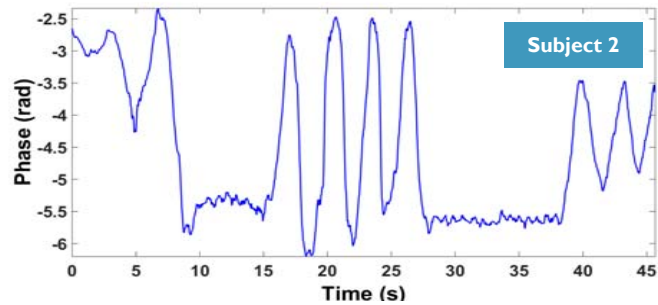
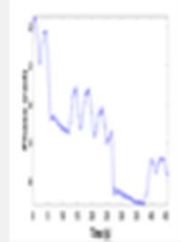
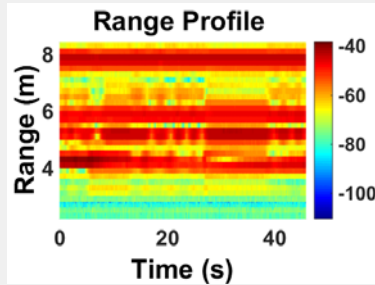
# BEYOND WEARABLES: non-contact health sensing



**Capacitive Bio-impedance based  
Respiration rate + depth sensing  
through shirt and sweater**



# BEYOND WEARABLES: non-contact health sensing



Heart rate and respiration rate  
extracted from 2 meters distance using radar





# Driver Health Monitoring

WHAT ABOUT THE LONGER TERM ?



**FACT**

**80% OF ALL CHRONIC DISEASES ARE LINKED TO OUR BEHAVIOR AND ARE IN PRINCIPLE PREVENTABLE**

# THE NEXT GENERATION





TOO MUCH SODIUM

- **90%**

DAILY VEGETABLES

- **62%**

DAILY FRUIT

- **64%**

## YOUNG ADULT OBESITY

---

- **19** % EU
- **27** % US

## INSUFFICIENTLY ACTIVE

---

- **34** % EU
- **52** % US







## STRESS AT WORK

■ **25%** OF YOUNG ADULTS ARE  
**VERY STRESSED AT WORK**



## SMOKING

- **19-32%** EU
- **17%** US
- **10-30%** JAPAN



## BINGE DRINKING

■ **15** % US & EU

**SO IT IS ONLY  
A MATTER OF  
TIME ...**



HOW CAN WE PREVENT THIS FROM  
HAPPENING ?



KNOWING THE SOLUTION IS NOT ENOUGH



CHANGING BEHAVIOR IS **SO** DIFFICULT

THIS NEEDS TO **CHANGE**



imec.iCHANGE

PERSONAL BEHAVIORAL TECHNOLOGY  
DISRUPTING PREVENTIVE HEALTH

# imec.iCHANGE



STOP SMOKING



STOP DRINKING



MEDICATION COMPLIANCE



MANAGE EATING DISORDERS



LOSE WEIGHT



BALANCED DIET



INCREASE FITNESS



ATHLETE PERFORMANCE



THERAPY FOLLOW-UP



PREVENT BURNOUT



PERSONAL INSIGHTS



INCREASE ENGAGEMENT



GET IN THE ZONE  
OPTIMIZE PERFORMANCE

BURNOUT, DEPRESSION

NOT JUST ABOUT **BAD** HABITS

COUNTLESS **POSITIVE** APPLICATIONS

BUT THERE IS A MAJOR CHALLENGE



**WE ARE ALL DIFFERENT AND UNIQUE**



**YOU  
MAY  
NEED  
A  
COACH**



**I  
MAY  
NEED  
A  
DRILL  
SERGEANT**



**THE CARROT  
VS  
THE STICK**



WHAT WORKS FOR **ME** MAY NOT  
WORK FOR **YOU**

WHAT WORKS FOR ME **TODAY** MAY  
NOT BE EFFECTIVE **TOMORROW**

# GO BEYOND **MOTIVATION**



**2017**  
**GOALS**

- 1.
- 2.
- 3.
- 4.

## FOCUS ON **PERSONAL ABILITY**

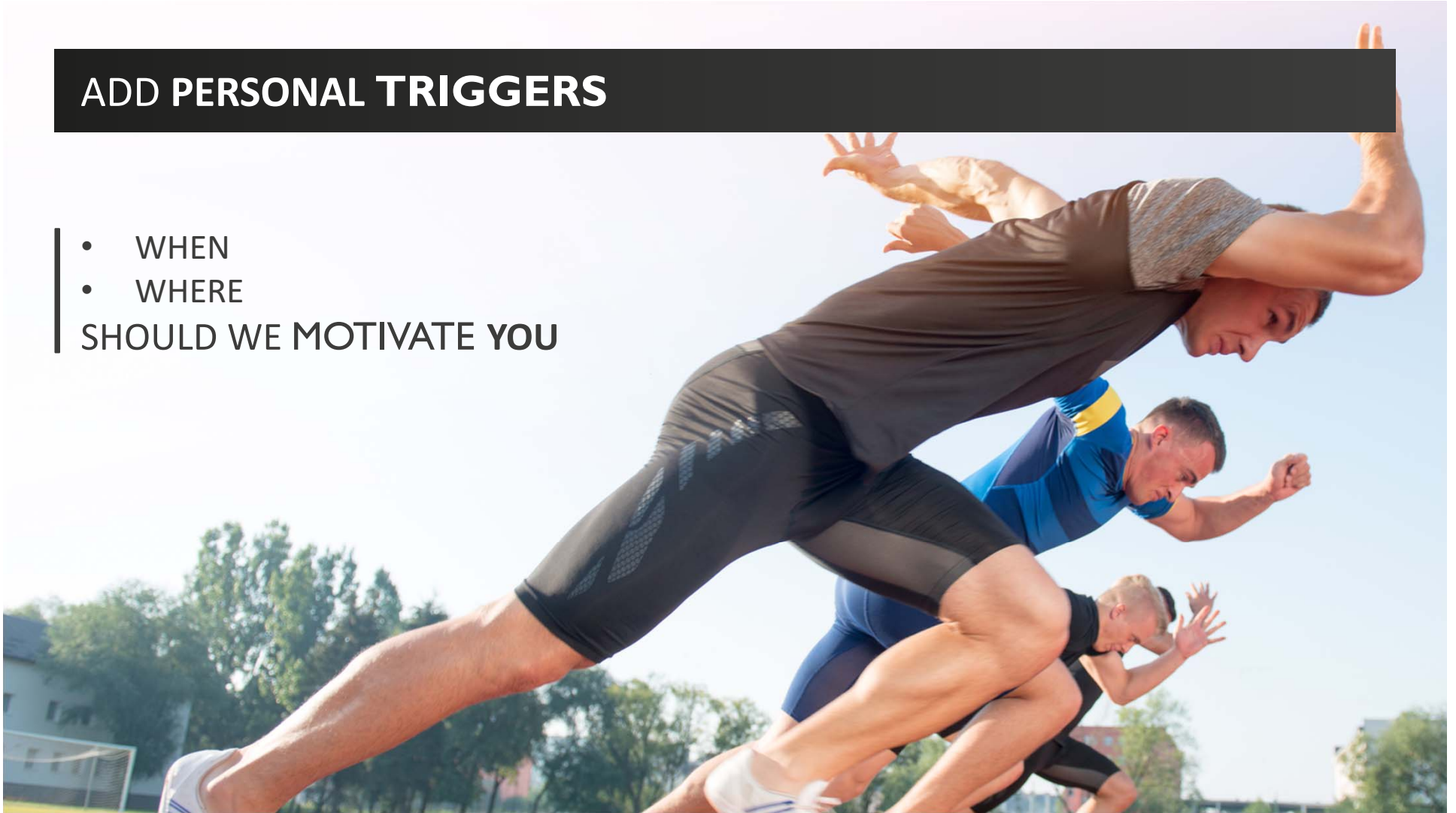
HOW **DIFFICULT** IS

- THE GOAL FOR YOU
- THE GOAL **PERCEIVED** BY YOU



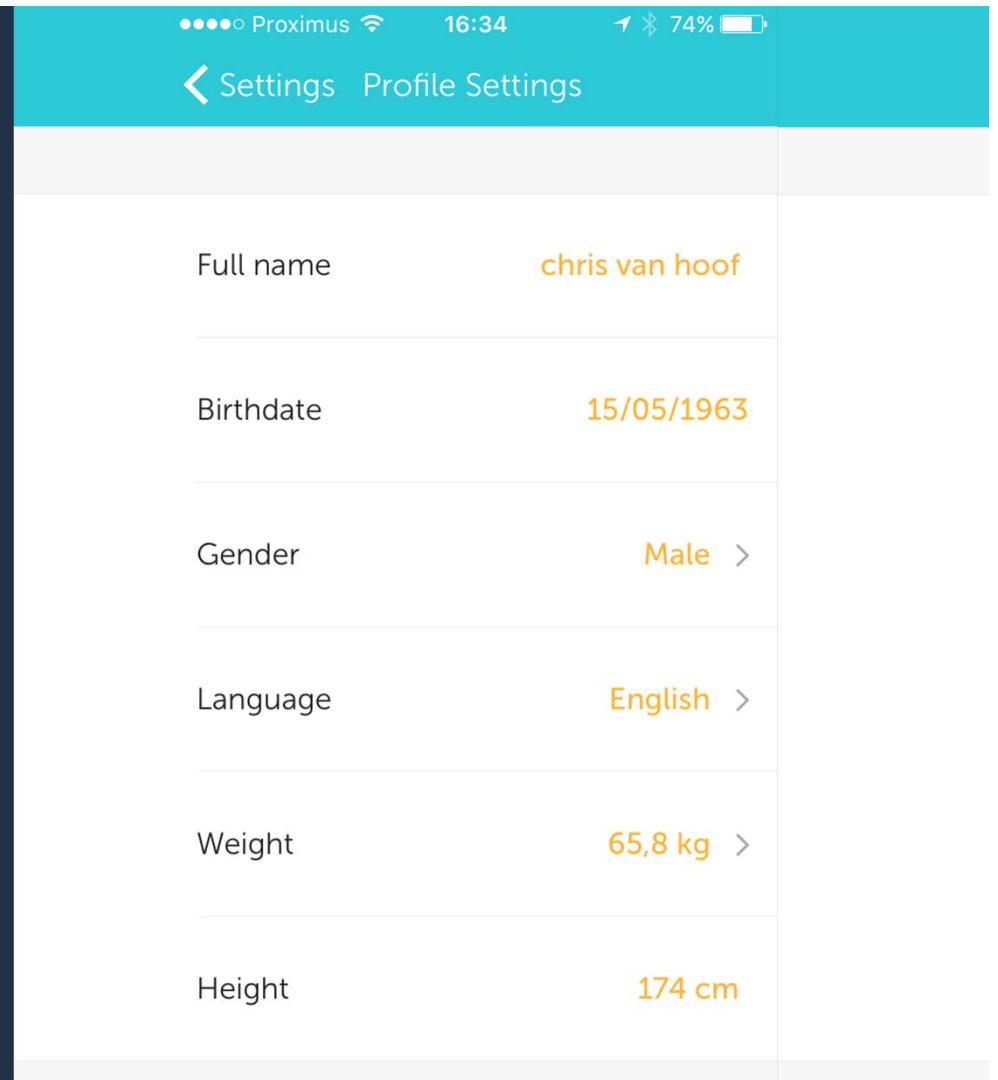
## ADD PERSONAL TRIGGERS

- WHEN
  - WHERE
- SHOULD WE MOTIVATE YOU



**PERSONALIZATION WILL BE KEY**

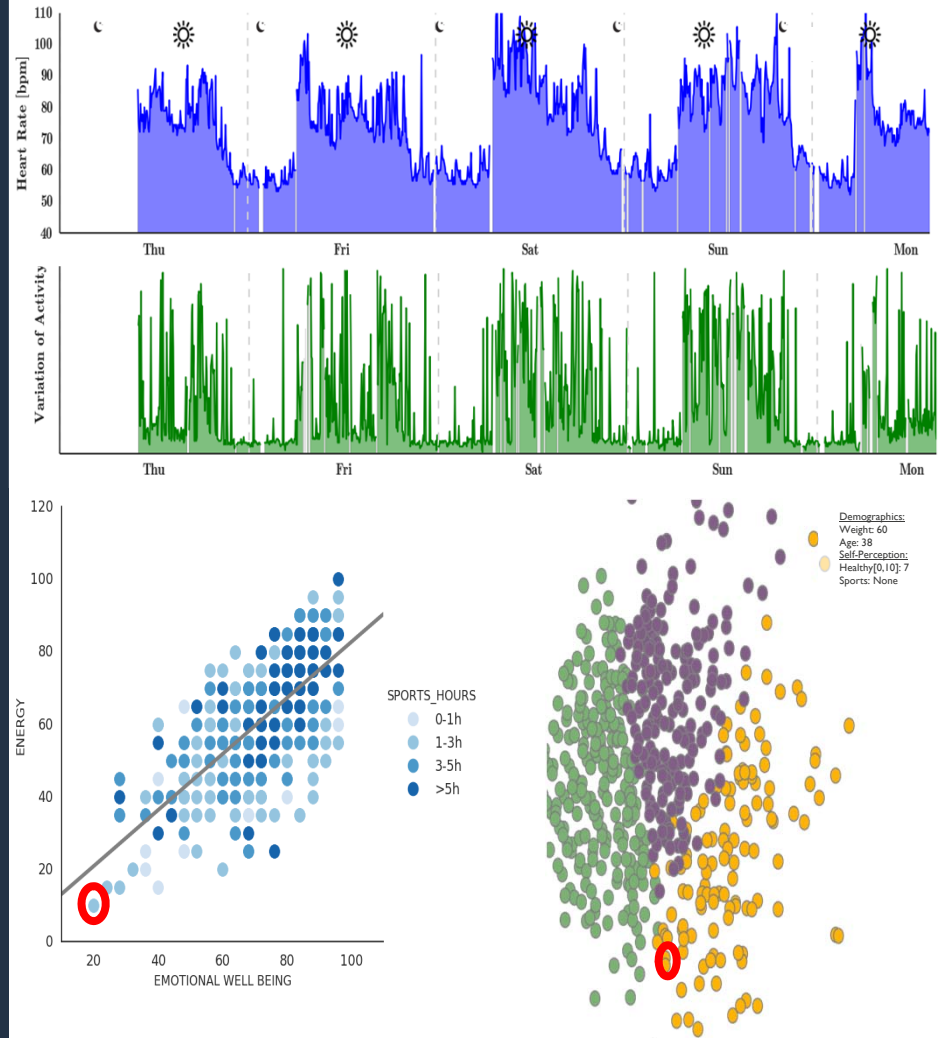
# PERSONALIZATION TODAY



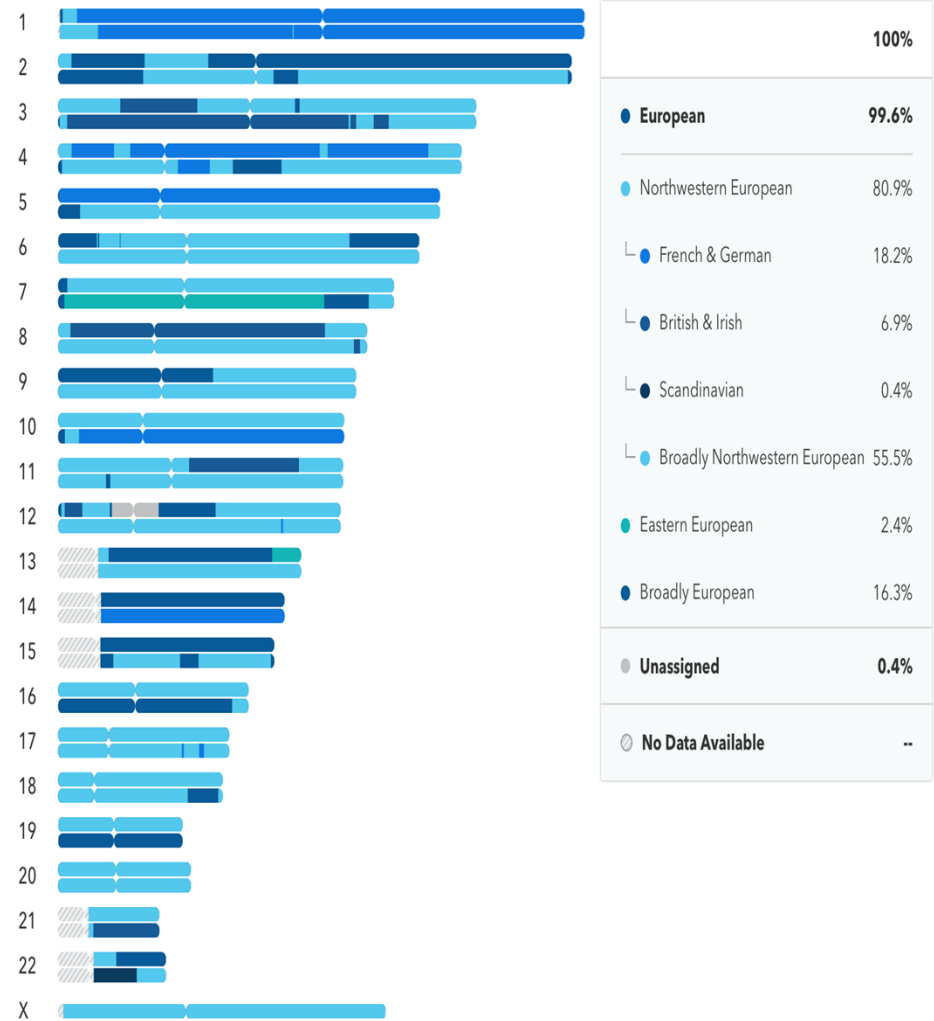
The image shows a mobile application interface for profile settings. The top status bar displays 'Proximus', signal strength, Wi-Fi, time '16:34', location, Bluetooth, and battery at '74%'. Below the status bar is a teal header with a back arrow and the text 'Settings Profile Settings'. The main content area is a list of profile fields, each with a label on the left and a value on the right. The values are in orange text. The fields are: Full name (chris van hoof), Birthdate (15/05/1963), Gender (Male >), Language (English >), Weight (65,8 kg >), and Height (174 cm).

Field	Value
Full name	chris van hoof
Birthdate	15/05/1963
Gender	Male >
Language	English >
Weight	65,8 kg >
Height	174 cm

# PERSONALIZATION TOMORROW



# PERSONALIZATION TOMORROW





**DIGITAL PHENOTYPING**  
WILL  
ENABLE  
**PERSONALIZATION**

# **DIGITAL PHENOTYPING**

CAPTURING AN INDIVIDUAL'S CHARACTERISTICS THROUGH TECHNOLOGY

- LEARN YOUR BEHAVIOR & HABITS & CRAVINGS
- FIND PATTERNS & TRIGGERS
- GIVE YOU THE RIGHT RECOMMENDATION AT THE RIGHT TIME
- FIND THE CORRELATIONS BETWEEN YOUR DIGITAL PHENOTYPE AND HEALTH DYNAMICS

**STRESS**





€ 63B IN EUROPE



€ 514B IN EUROPE

# SWEET STUDY – STRESS IN THE WORK ENVIRONMENT

A MULTI-SENSOR, MULTI-ANALYTIC STUDY

## PHYSIOLOGICAL



CHILLBAND

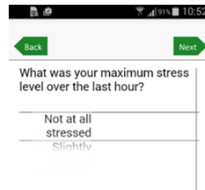
GSR  
Temperature  
Acceleration (3 dim)



CHEST PATCH

ECG  
Acceleration (3 dim)

## SMARTPHONE



QUESTIONNAIRES

Stress  
Activity  
Food/beverage intake  
Sleep  
Gastro intestinal symptoms



LOCATION

Continuous  
During questionnaires



VOICE



PHONE DATA

Proximity  
Acceleration  
Step count  
Screen on/off  
Ambient light  
Temperature  
Humidity  
...

## WEBSITE



QUESTIONNAIRES

Baseline information

# SWEET STUDY – STRESS IN THE WORK ENVIRONMENT

SOME NUMBERS

1 002 SUBJECTS



11 COMPANIES



5 TB DATA



26,000 SELF-  
REPORTED  
STRESS  
RESPONSES



95,000 HOURS  
PHYSIOLOGICAL  
DATA

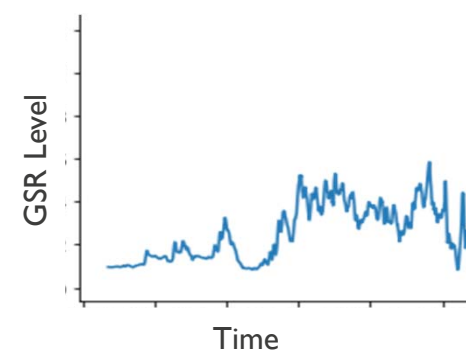
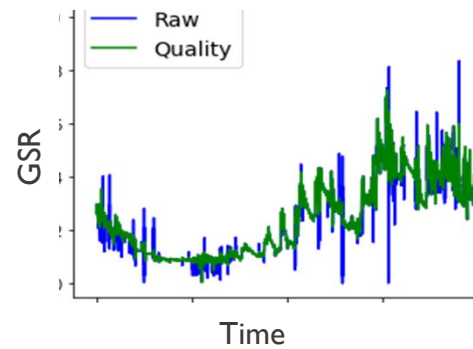
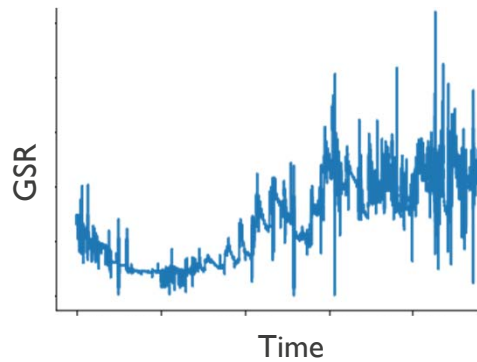
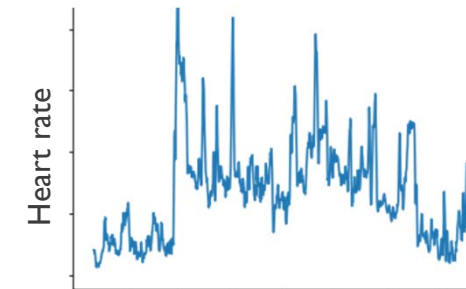
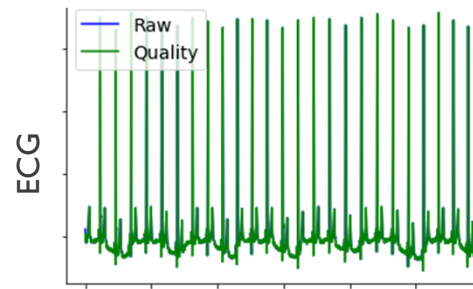
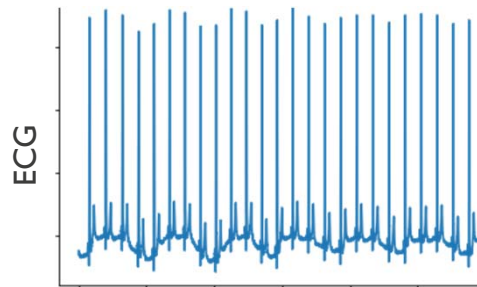


# PREPROCESSING 90,000 HOURS OF PHYSIOLOGICAL DATA RELATED TO MENTAL STRESS THROUGH AI

RAW DATA

HIGH QUALITY DATA

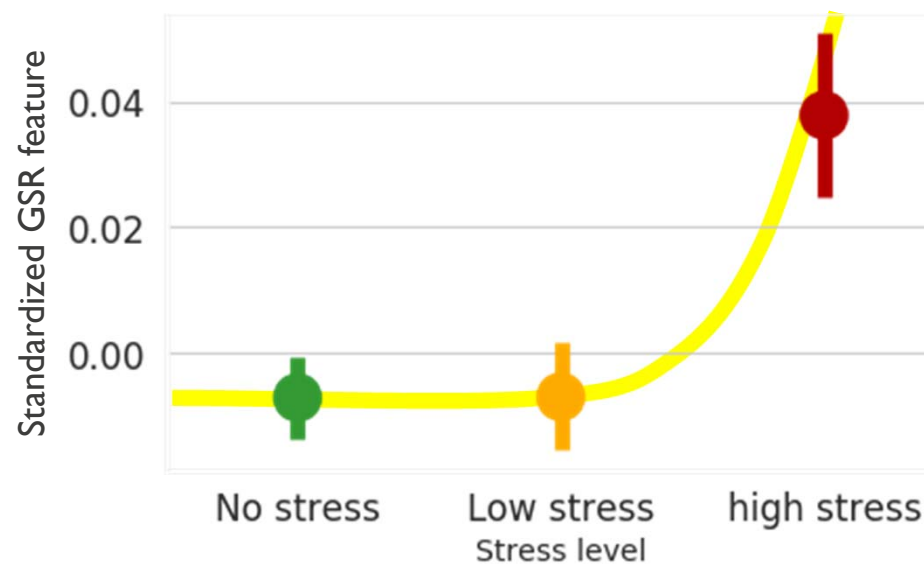
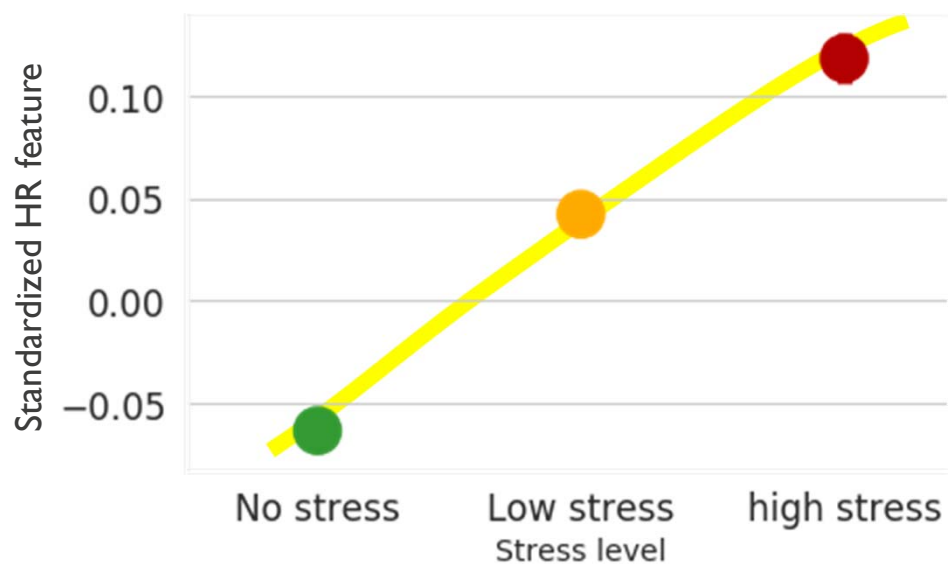
FEATURES



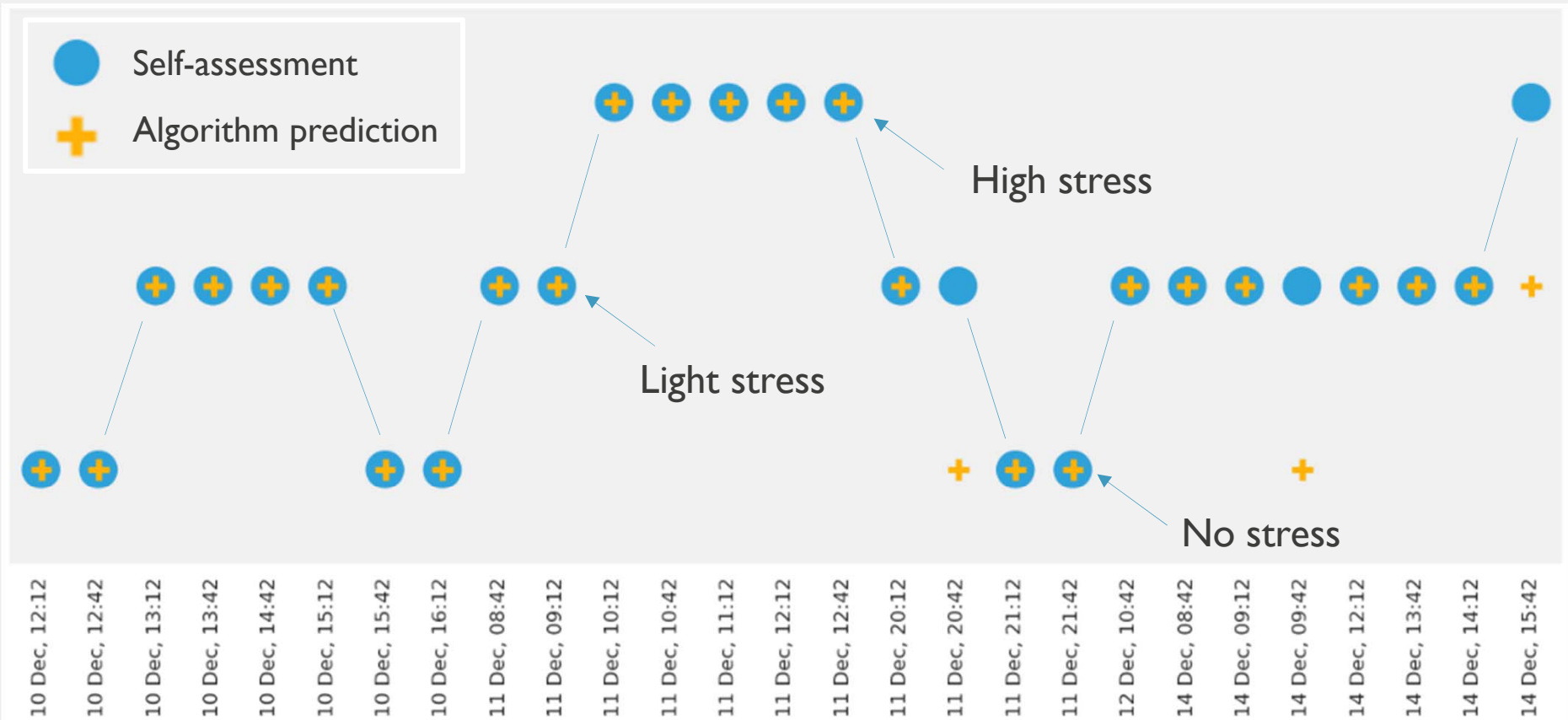


## CLEAR TRENDS ACROSS THE ENTIRE TEST POPULATION

IMPORTANCE OF PERSONALIZED MODELS: classification accuracy is only achieved through individual normalization and COMBINATION of features

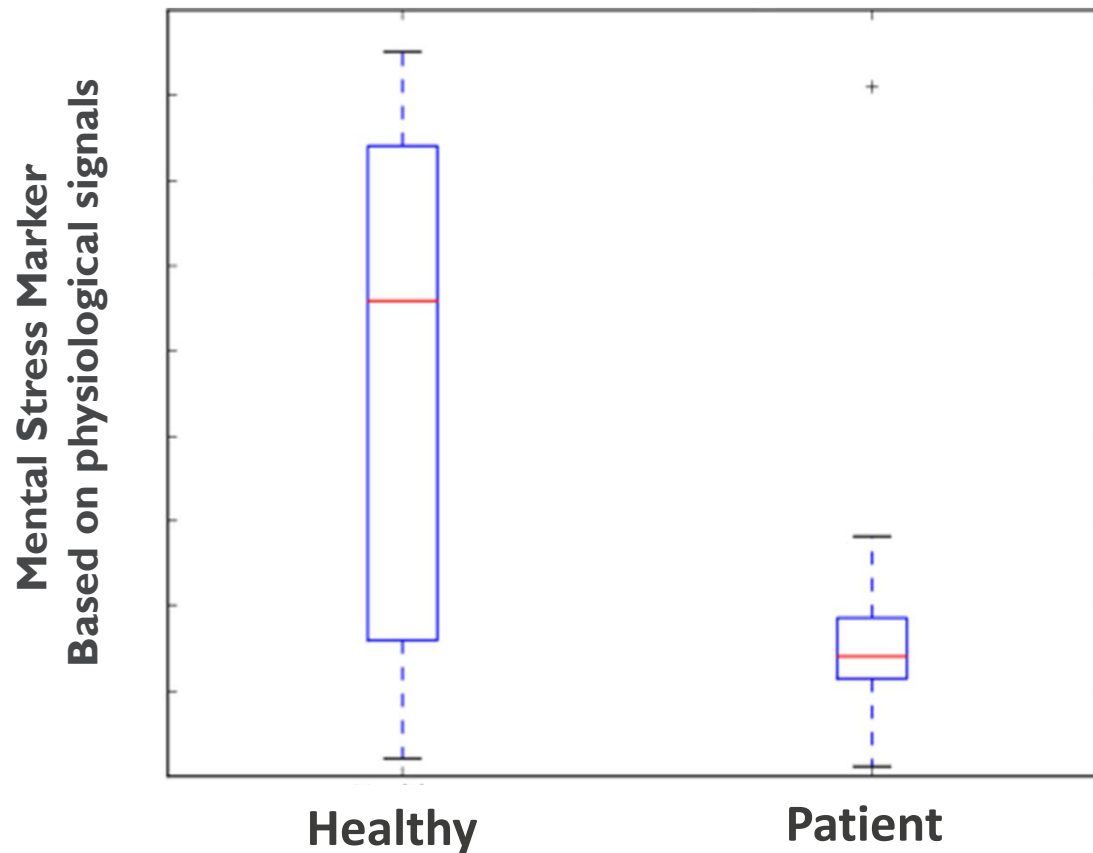


# STRESS PREDICTION ALGORITHM MATCHES WITH SELF ASSESSMENT



# CAN WE APPLY THIS TO PREDICTIVE HEALTH ?

INITIAL STUDY LOOKING AT HEALTHY PEOPLE AND PATIENTS WITH STRESS DISORDER



**91%**  
sensitivity  
of patient  
detection

**SMOKING**

HOME

ABOUT THE STUDY

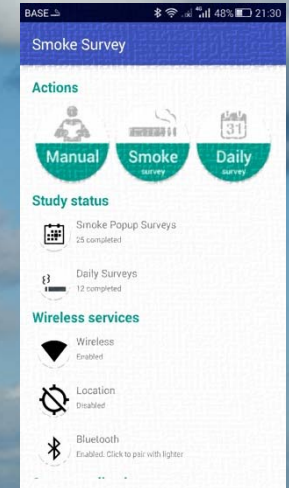
PARTICIPATE

LOGIN



# ASSIST study

By imec Wearable Health

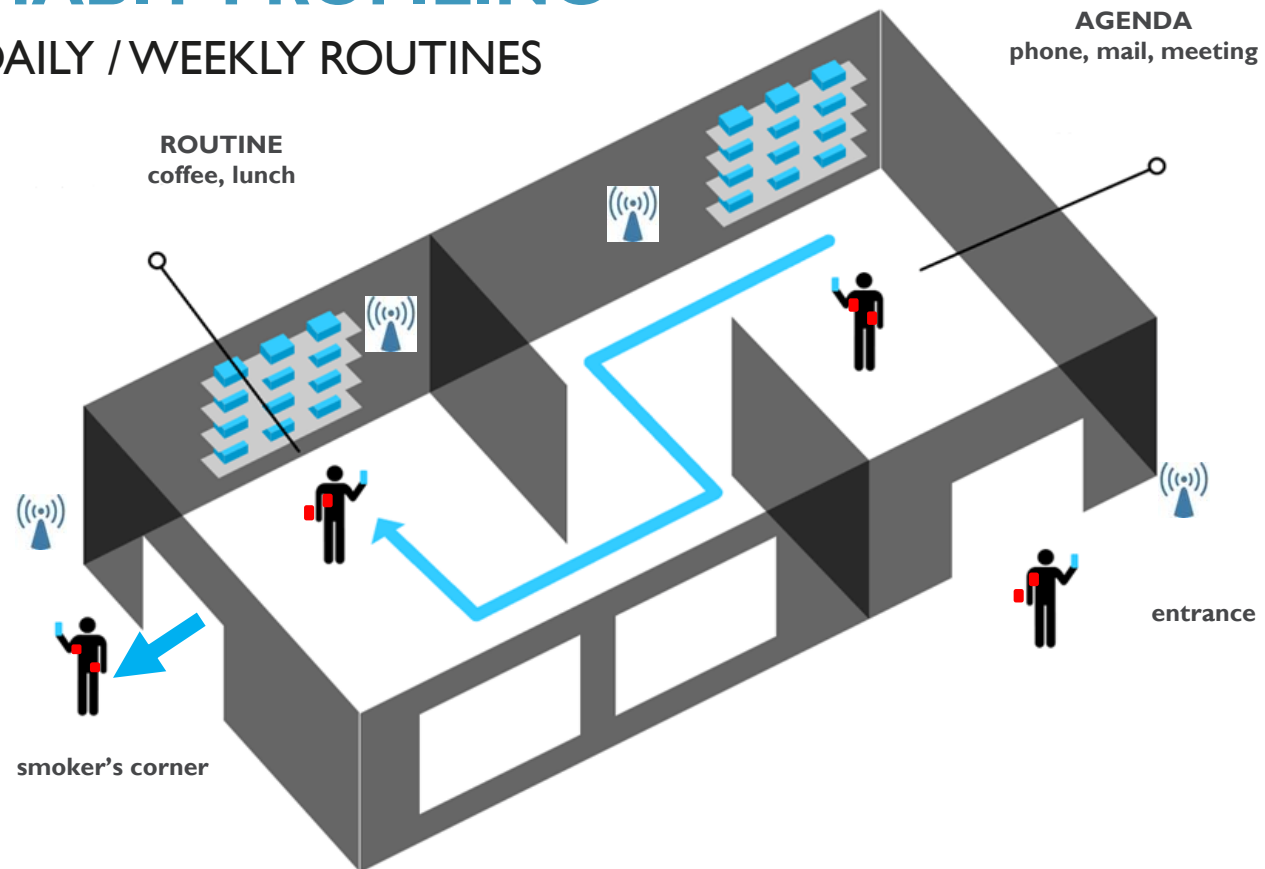


## A smoking behaviour study by imec

Welcome to the ASSIST study. This study aims to understand smoking behaviour and take actions to decrease smoking.

# SMOKING HABIT PROFILING

## DETECTION OF DAILY / WEEKLY ROUTINES



### STUDIES:

Pilot study of smoking (2 weeks) completed

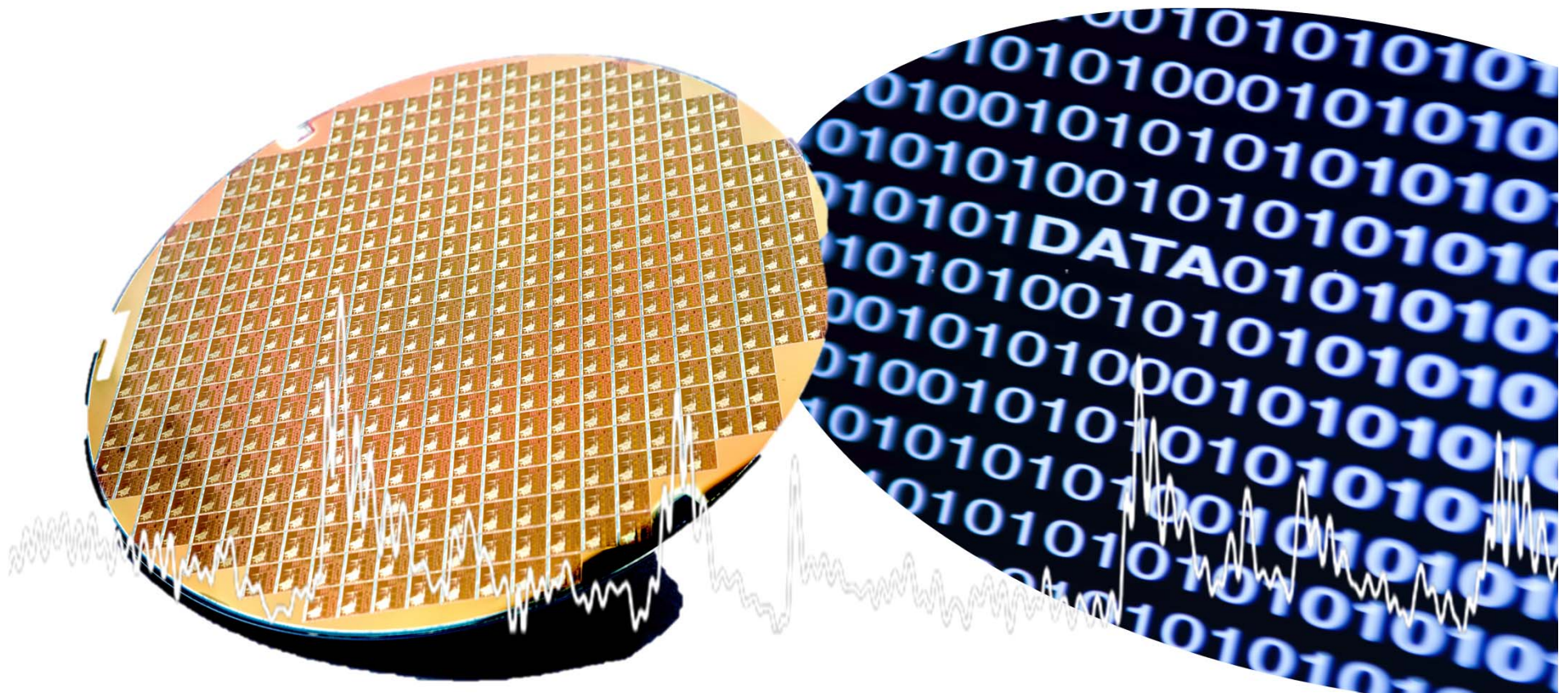
Large scale trial (100 smokers, 4 weeks) in recruitment

# EATING DISORDERS



LONGITUDINAL STUDIES  
TOOL DURING THERAPY

# TECHNOLOGY & DATA SCIENCE INNOVATIONS WILL ENABLE PERSONAL BEHAVIOR CHANGE







IMEC.CHANGE  
AN **INTERDISCIPLINARY** APPROACH

APP  
DEVELOPERS

BUSINESS  
DEVELOPERS

SOCIOLOGISTS

SENSOR &  
TECHNOLOGY  
R&D

DATA  
SCIENTISTS

PSYCHOLOGISTS  
CLINICIANS

**WEARABLES** ARE NO LONGER STAYING **PASSIVE**

THEY ARE BECOMING AN **ACTIVE**  
CONTRIBUTOR TO OUR **WELLBEING**

# DIGITAL BEHAVIORAL TECHNOLOGY

## A STEPPING STONE TO PREVENTIVE HEALTH



# imec.iCHANGE



STOP SMOKING



STOP DRINKING



MEDICATION COMPLIANCE



MANAGE EATING DISORDERS



LOSE WEIGHT



BALANCED DIET



INCREASE FITNESS



ATHLETE PERFORMANCE



THERAPY FOLLOW-UP



PREVENT BURNOUT



PERSONAL INSIGHTS



INCREASE ENGAGEMENT



GET IN THE ZONE  
OPTIMIZE PERFORMANCE

BURNOUT, DEPRESSION



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WIRELESS SENSORS FOR PREVENTION, CURE AND CARE

CHRIS VAN HOOFF – senior director personal health solutions, imec  
imec Fellow, professor KU Leuven

