EnableYourWear – Human-centric Assistance as Market Driver for Wearables an Big-data

Fraunhofer Institute for Integrated Circuits IIS
Image Processing and Medical Engineering department

Dipl.-Inf. Christian Weigand, head of department

02 Mai 2017

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Contents/Agenda

- What to measure
- Wearables & market – where we are now
  - Consumer Products, e.g. Fitness Trackers – lack of sustained use
  - Applications for specific user groups
  - »Serious« Health Products – to be regulated / clinical-grade
- General success criteria for wearables
  - »Clinical Grade« Wearables – emerging market, specific requirements
  - Textile Integration
- Examples
  - FitnessSHIRT, ambiotex shirt, ECG-Shirt
- Conclusion

Image Processing and Medical Engineering

Fraunhofer IIS – At a Glance

- Founded in 1985
- Staff: 950 employees
- Budget: 130 Mio. € in 2015
- Revenue sources:
  - > 75% income from projects
  - < 25% public funding
- Locations:
  - **Erlangen**, Nuremberg, Fürth, Dresden, Ilmenau, Würzburg, Bamberg, Deggendorf, Coburg, Waischenfeld

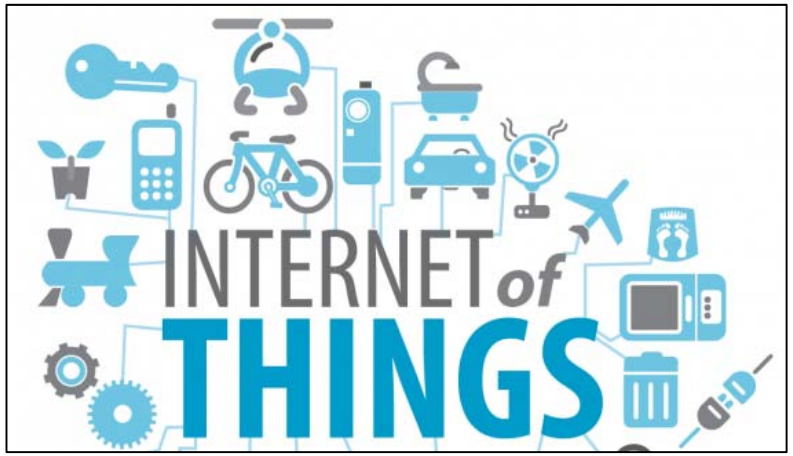
METEAN

Fraunhofer IIS

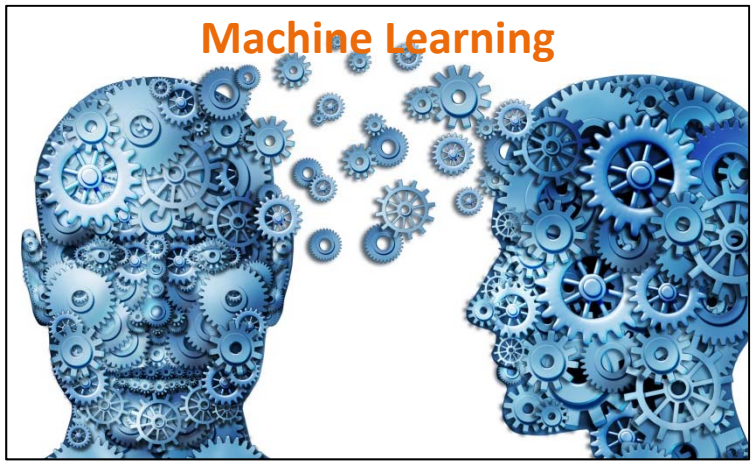
Image Processing and Medical Engineering

Researchtopics of today

Quelle: http://eck-marketing.de



Quelle: https://www.linkedin.com



Quelle: http://stamfordresearch.com

Quelle: http://wiss-netz.de

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Classification of »Biosignals«

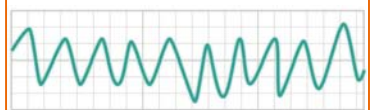
Biosignal

electrical

EKG

EOG

EEG



acoustical

speech

sound

mechanical

gesture

facial expression

movement

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Classification of »Biosignals«

Biosignals

chemical

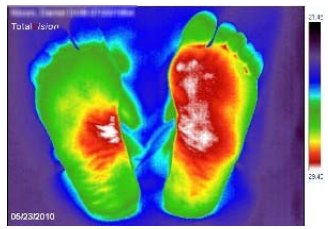
urine

blood

smell

thermal

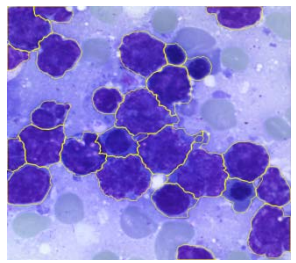
temperature



optical

3D-Scan CT

microscopy



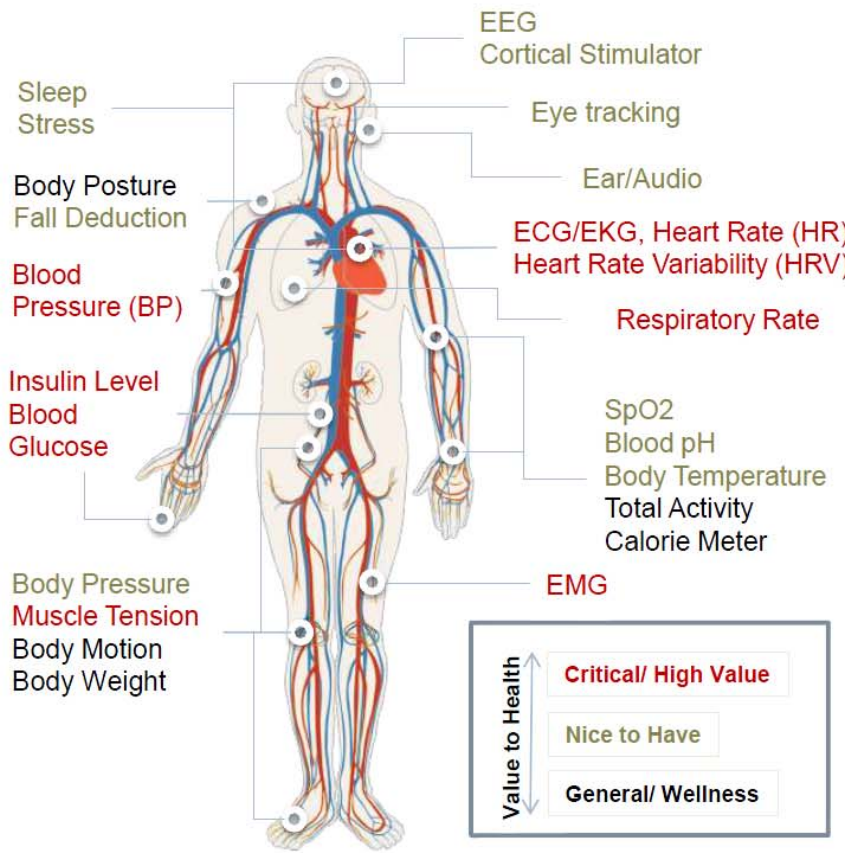
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Biometrics that Can be Tracked by Wearables

Wearables Harnessing Human Body Data/ Biometrics



Major Therapeutic Focus

Heart and Cardio Monitors

ECG/EKG, HR, HVR		CVD, MI, Stroke Arrhythmias Atrial Fibrillation
Temperature Fall Deduction	Respiratory Rate, BP	

Diabetes and Obesity Monitors

Blood Glucose Insulin	Body Pressure	Diabetes Hypoglycemia Obesity
Respiratory Rate, BP	HR, Vision Body Weight	

Respiratory and COPD Monitors

ECG, HR, SpO2, Respiratory Rate		COPD Asthma Tuberculosis Lung Cancer Respiratory Infection
Temperature Fall Deduction	Activity Body Posture	

Chronic Pain Management

Body Pressure Muscle Tension	Body Posture Fall Deduction	Headaches Joint Pain Lower backaches
Body Motion Body Weight	Total Activity Sleep	

Source: Frost & Sullivan

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Activity / Fitness Trackers: Market Success – but…

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Activity / Fitness Trackers: Market Success – but Lack of Sustained Use!

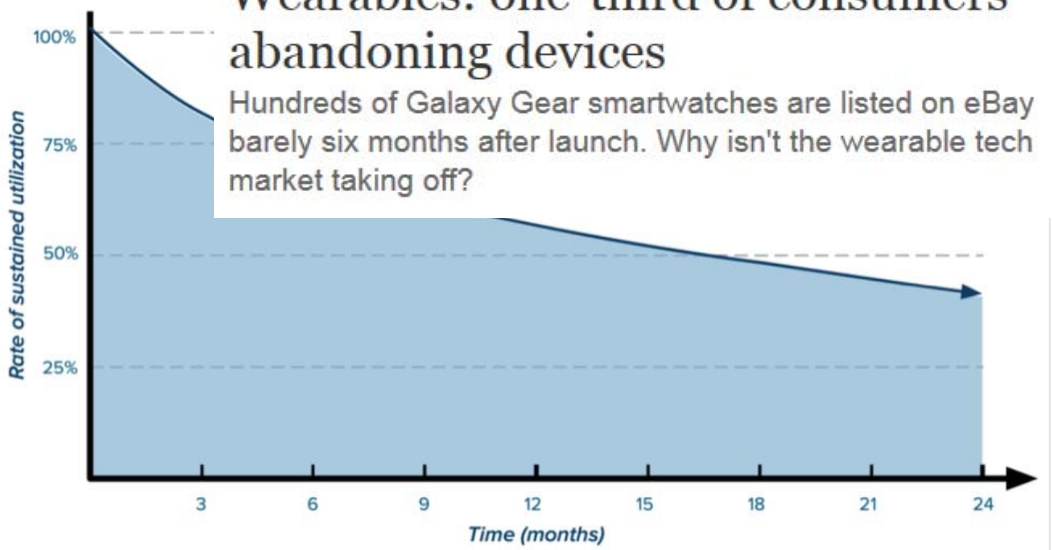
theguardian

News | Sport | Comment | Culture | Business | Money | Life &

News › Technology › Wearable technology

Wearables: one-third of consumers abandoning devices

Hundreds of Galaxy Gear smartwatches are listed on eBay barely six months after launch. Why isn't the wearable tech market taking off?



Declining Rate of Sustained Activity Tracker Use Over Ownership
(Endeavour Partners, September 2013)

The 9 Baseline Criteria

Each of the criteria below must be met to drive initial adoption and utilization; however, these criteria alone are not sufficient to drive long-term utilization

Selectability / Adoptability - The clarity, relevance and uniqueness of the value proposition to consumers is essential for adoption; there are many similar choices in the market and consumers are generally not familiar with this category of devices and services, making selection a potentially stressful experience.

Design / Aesthetics - The majority of wearable products today are worn in a manner in which they are visible. The aesthetics of a product are therefore critical. Companies that embrace design elegance over breadth of features are more likely to find users wearing their products for a longer period of time.

Out-of-Box / Setup Experience - The quality of the initial experience with a product or service is critical. Companies starting from an idealized out-of-box experience will likely achieve a far more pleasant and lasting initial experience than those that don't.

Fit / Comfort / Form Factor - The fit and overall comfort of a device are critical for adoption and sustained utilization. This extends well beyond the comfort of simply wearing the device. Other common activities need to be considered. For example, wrist-worn wearables with thicker bands can quickly become irritating in a number of different activities like typing on a laptop.

Quality / Robustness - As Jawbone experienced in its initial launch of the Jawbone Up, building a reliable wearable device is hard. A device that is designed to be worn on the wrist throughout all of life's activities experiences a high degree of wear and tear.

User Experience - The user experience must be immediately intuitive, familiar and seamless which must transcend the device, the mobile app, web-services, and overall support.

API / Integratability - Many devices and services support APIs such that data can be accessed by other services to create new types of benefits for the users. As more services become available that can leverage this data, the overall experience improves.

Lifestyle Compatibility - The less behavior change a device requires in order to simply wear it, the more likely that it will drive longer term engagement. The more times per week the user is required to take the device off (to charge or sync the device, or to take a shower), the more likely they are to abandon it.

Overall Utility - Wearable devices and services built around them need to be designed with a clear intent of how they will help people. Products and services that gather data, and simply provide distillations of that data without a clear purpose will fail to achieve any sustained utilization.

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Smart Ecosystem

BOLTT connected shoes, stride sensor, fitness trackers and virtual health assistant

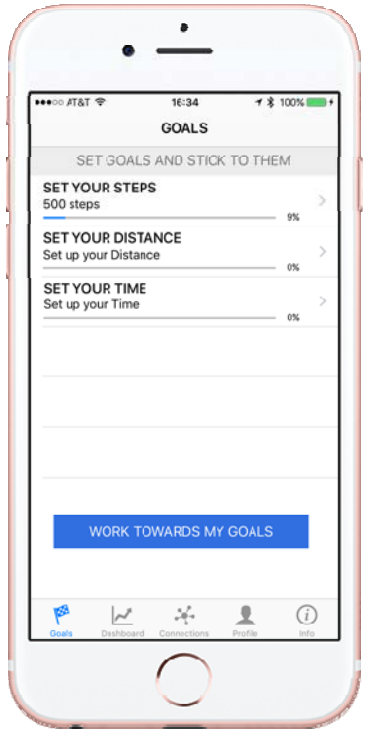
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Activity Tracking

Sensoria Socks + App



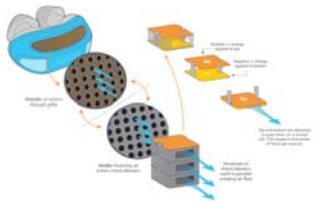
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Sleep Quality - Obstructive Sleep Apnea

2breathe Sleep Inducer vs. Airing Hoseless, Maskless, Micro CPAP



METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

In-Ear Devices With »Medical« Functions

- Bragi Dash: All in one device
  - Pulse oximeter (Pulse, oxigene saturation)
  - Thermometer
  - Fitness Tracker
  - MP3 Player
  - Noise-cancelling Headphone / Headset
- Cosinuss Earconnect
  - Pulse meter
  - Thermometer
  - Headphone

➔ **Standalone consumer devices without »serious« medical application perspective**

Bragi Dash

Cosinuss Earconnect

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Benefits to Healthcare Stakeholders

Decentralization, Mobility, Efficiency

Benefits to Different Stakeholders

Hospital

Reduces readmission, patient process time, and test duplication

Physician

Can access comprehensive patient data and history for improved decision making and diagnosis

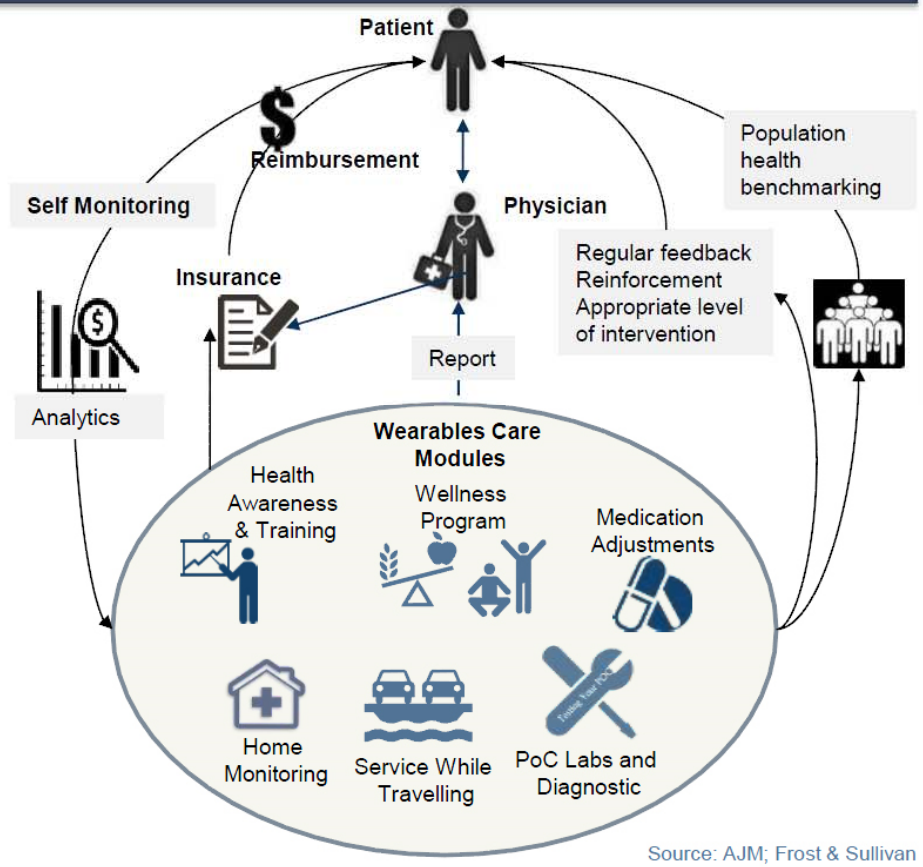
Patient

Can stay more informed about personal health and wellness, and benefit from reduced treatment time

Payer

Reduced treatment cost, hospital length of stay, and overall process efficiency

Wearable-Enabled Decentralized Care Model by 2020



Source: AJM; Frost & Sullivan

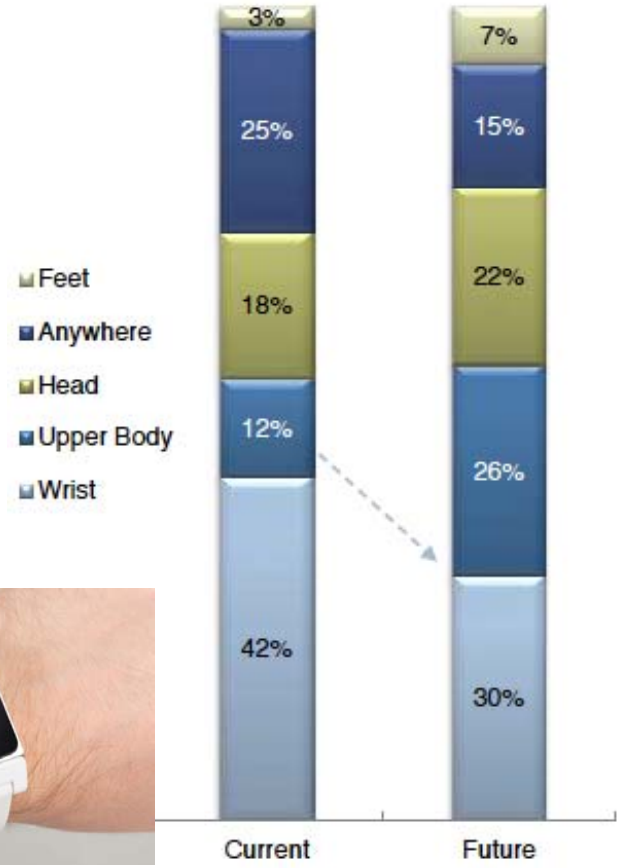
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Consumer Health Wearables Segment: Illustrative Wrist Wearbles and Error Rates

- In monitoring accurate health vitals, wrist-based sensors face the most challenges
- Differences in skin pigmentation and narrow blood capillaries in the wrist make it difficult for wrist wearables to capture accurate readings for health vitals such as heart rate and blood pressure or SpO2
- **Digitaltrends.com: »Forget bands, make more smart clothes«**



Examples of Wrist Wearable Devices	Error (%) at 80–90 BPM	Error (%) at 160–170 BPM
Garmin VivoFit	10.7	0
Withings Pulse O2	5.3	57.1
Basis Carbon Steel	10.2	57.9
Samsung Gear Fit	4.2	Unable to read
Samsung Galaxy S5	3.1	0.2

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Wearables vs. Clinical Grade Wearables

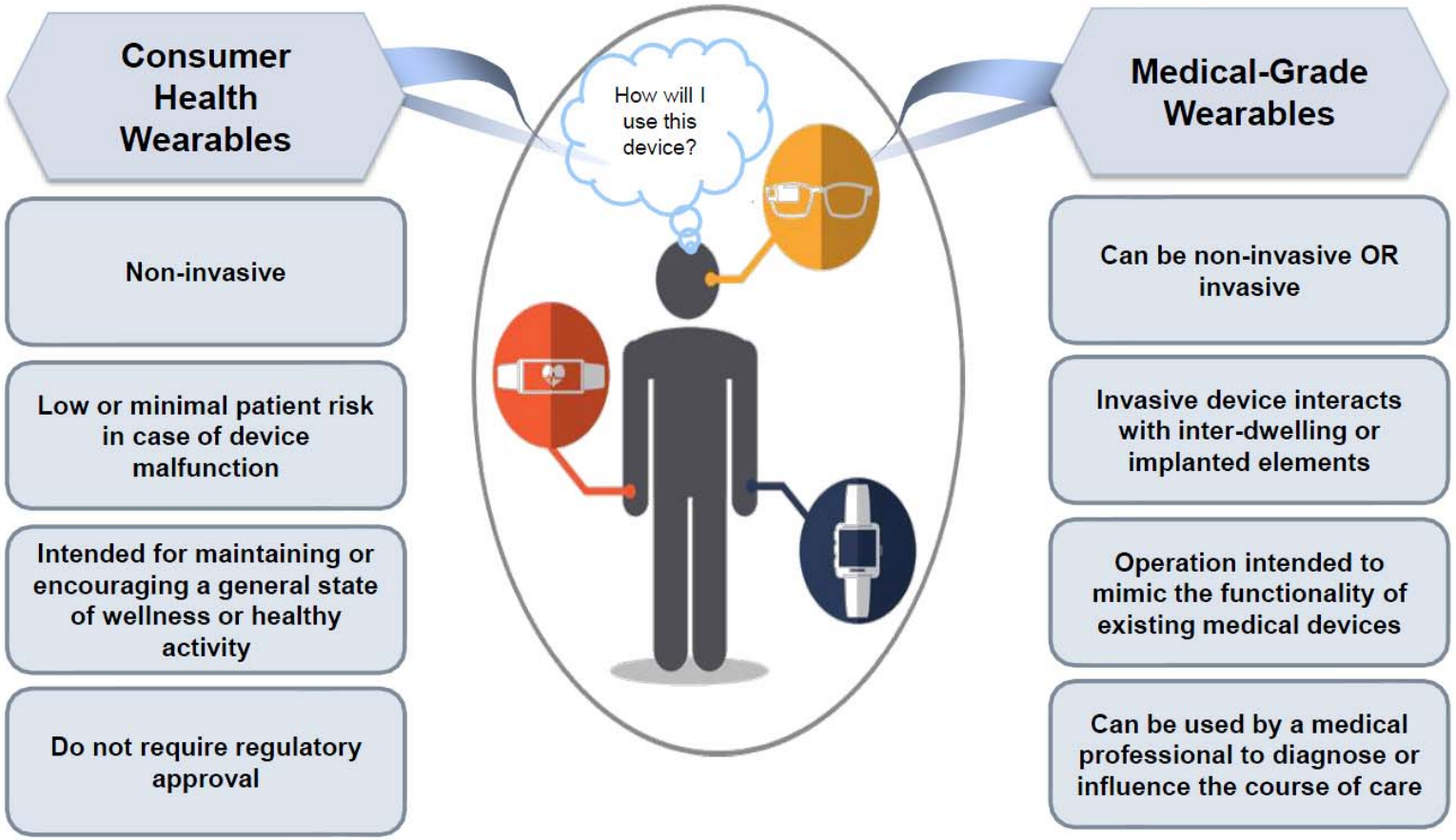
- So what do do with wearables?

- First of all: wearables have to become more reliable
- For becoming more reliable don’t choose the wrist
- To add value become a clinical/medical grade wearable

Image Processing and Medical Engineering

Consumer vs. Medical-Grade Wearables

Characteristics & Potentials



Source: Frost & Sullivan

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Consumer and Clinical-Grade Markets – Snaphot 2015 & Forecast for 2020

The global market for wearables in healthcare is expected to reach a revenue of $18.9 billion in 2020, growing at a CAGR of 29.9%.

Wellness, Fitness, and Sports (Unregulated)

2015 $3.1B
NA 44.2% EU 37.5%
APAC 10.8% ROW 7.5%

2020 $10.6B
NA 40.7% EU 35.8%
APAC 12.4% ROW 11.1%

- The non-regulated wellness, fitness, and sports wearable segment is expected to grow at CAGR of 27.8% (2015–2020).
  - Commoditization of unregulated wearables is expected to increase competition for leading participants such as Nike, Jawbone, Fitbit, and Samsung.
  - Demand for specific wellness and fitness wearables that lack clinical relevance (wristbands, sports watches, and smart garments) is expected to shrink in the near future.

Medical and Clinical (Regulated)

2015 $2.0B
NA 51.8% EU 26.0%
APAC 15.8% ROW 6.4%

2020 $8.3B
NA 44.0% EU 25.0%
APAC 20.2% ROW 10.8%

- Regulated/clinical-grade wearables is the most promising product segment within healthcare wearables and is expected to grow at a CAGR of 32.9% (2015–2020).
  - During 2015, wearable devices transitioned from single usability to multi-functional clinical use cases (i.e., V0.1 to V0.2)
  - The increasing need for an integrated healthcare system and a rise in demand in the diagnostic industry are expected to drive the growth of this segment

Source: Frost & Sullivan

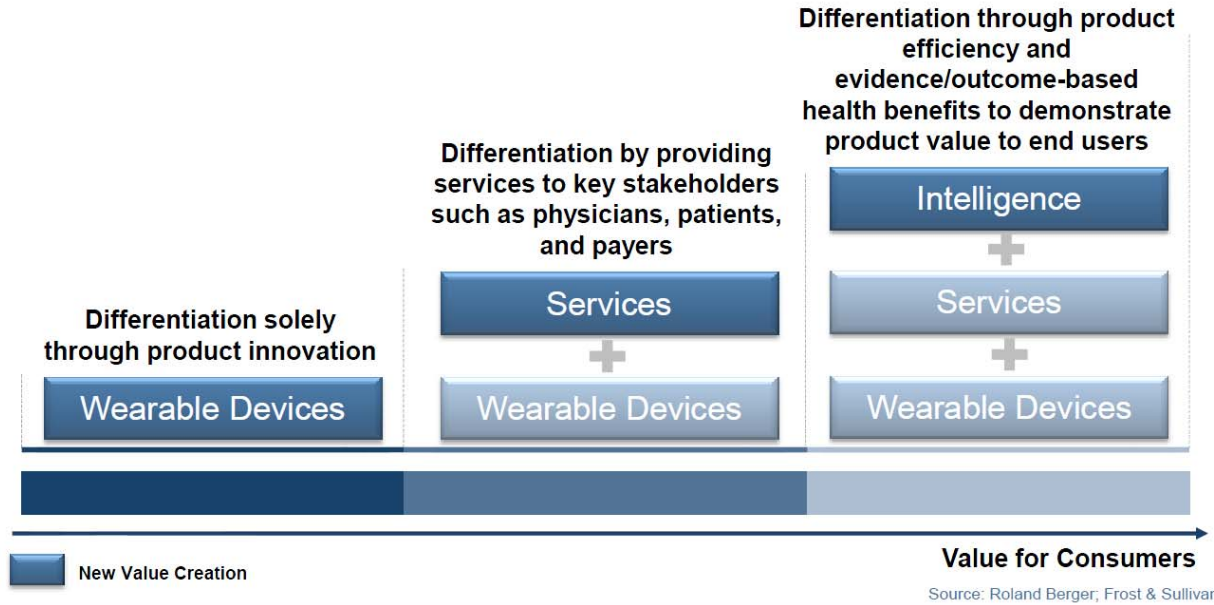
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering
»Clinical Grade« Wearables

- »Clinical Grade« Wearables – More than Devices
- Added value by Integrating Devices, Services & Intelligence

- Although the market landscape is dominated by consumer wearable devices, the average customer engagement time is decreasing (average of 6 months in 2015).
- This provides the opportunity for wearables that go beyond product to provide platform-based actionable intelligence solutions for sustainable revenue streams.



Source: Roland Berger; Frost & Sullivan

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Heart Rate Variability

- … is an indicator for the variation of the time between two R-peaks (RR-Interval)
- … is considered as a measure in terms of performance of cardiovascular mechanisms and indicator of neuro-vegetative activities as well as functionality of the heart muscle
- … gives information on the load to the cardiovascular system and the quality of respective body regulation
- … is the basis for the interpretation of proper balance of body performance Sympathicus) und regeneration (Parasympathicus)

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Heart Rate Variability

- 24 h analysis of the heart rate variability in frequency domain
- Short-Time Fourier Transform (5 min wnd, 75% overlap) for visualization

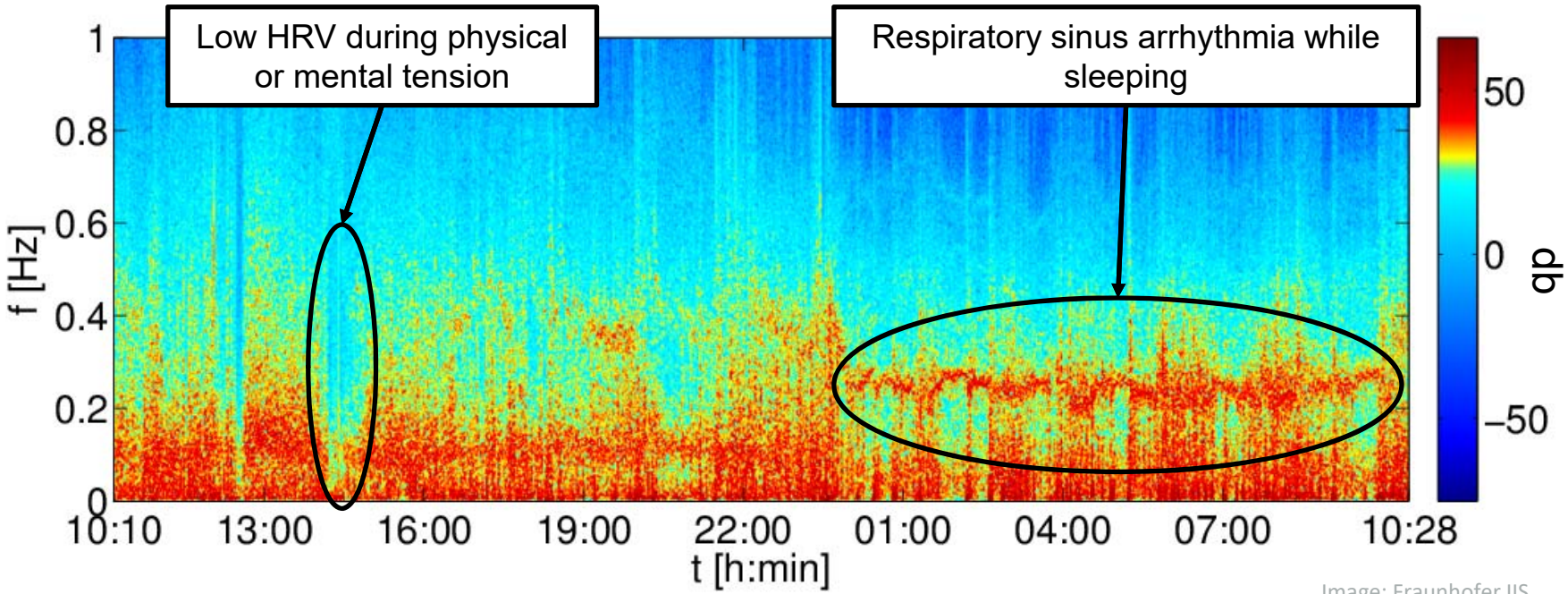


Image: Fraunhofer IIS

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

General Success Criteria for Wearables – as identified by recent publications

- Criteria for short-term utilization
  - clear and relevant user benefit
  - design and form factor
  - **quality and robustness**
  - intuitive, familiar and seamless user experience
  - **lifestyle compatibility / minimized need for behavior change**
    → **textiles enable solutions for unconscious use**
  - Integrateability by open APIs and data interfaces
    → **indispensable for »serious« and professional use cases**
  - product utility that must go much **beyond mere collections of data**
- Behavioral science factors for long-term utilization
  - **habit formation**
    → **textiles utilize everyday routines**
  - social motivation
  - goal reinforcement

➔ **Textiles enable optimal products for critical applications & users**

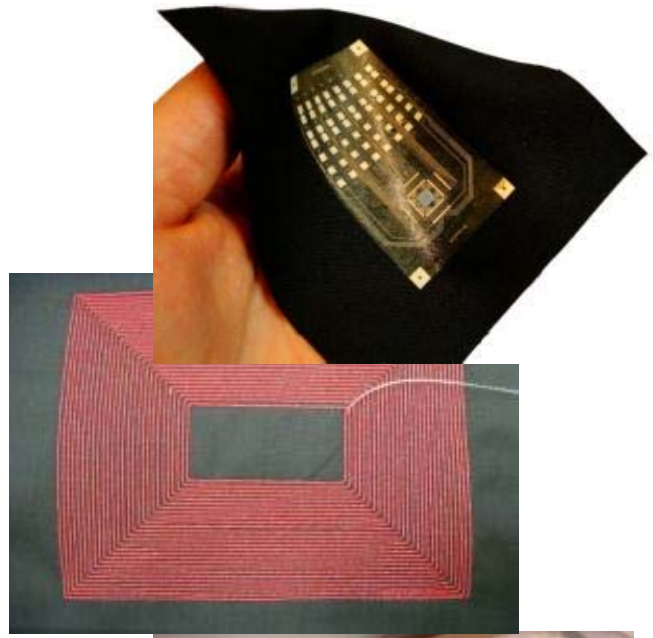
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Textile Integration Technologies – New Options for Wearables

- Textiles
  - integrate sensor, user interface and processing functions
  - provide intuitive use for all user groups
- Technologies
  - Flexible and stretchable substrates
  - Stitched or woven conducting paths
  - Novel contacting: stitched / bonded with thermoplastic polymers / crimped / integration of simple components into threads
  - Wireless interfaces (communication and battery charging)



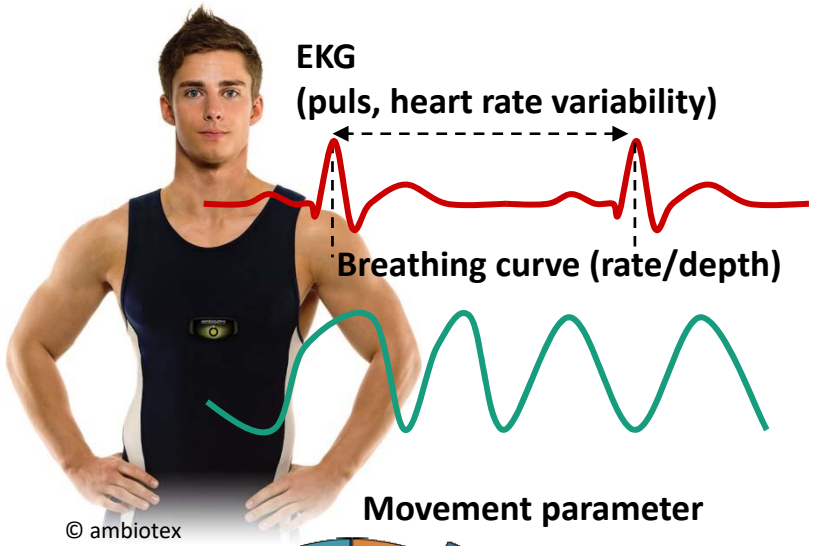
METEAN

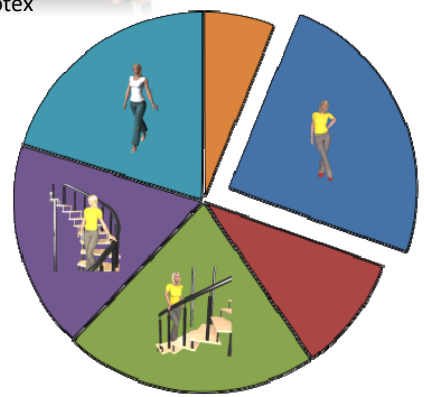
Fraunhofer IIS

Image Processing and Medical Engineering

FitnessSHIRT – Vital Signs Monitoring Wearable for Fitness / Sports / Medical Use

- 1-channel ECG with textile ECG electrodes
- Textile sensor belt for respiration registration
- Acceleration sensor for motion registration
- Sensors for temperature and transpiration
- Calculation and (BT-LE) transmission of:
  - heart rate / heart rate variability
  - respiratory rate (from respiration curve)
  - activity amount & type, fall events (from acceleration)
- For Training data acquisition and Monitoring of patients at risk and persons in critical environments





Quelle: Fraunhofer IIS

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Consumer Wearable – ambiotex shirt

Quelle: http://ambiotex.com

Quelle: http://ambiotex.com

METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Medical Grade Wearable – Multichannel ECG

Textile Integrated Multichannel ECG

- Detachable electronics at chest
- 7 integrated textile electrodes
- 3 Einthoven leads (I, II, III)
- 3 Goldberger leads (aVR, aVL, aVF)
- 3 Wilson leads (V1, V3, V5)
- Reference electrode RL as Driven Right Leg
  - Common mode rejection
- Textile isolated cables

Quelle: Fraunhofer IIS

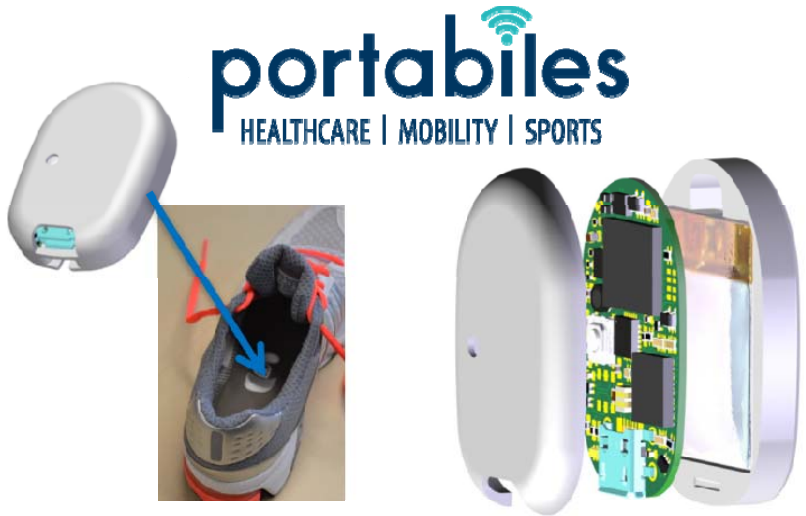
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

eGaIT – automatic gait analyses

- embedded gait analysis using intelligent sensor
- Worn at the foot
- Textile integration in shoe



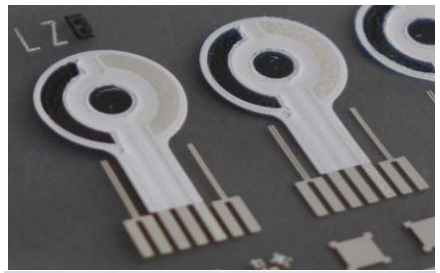
METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Sophisticated printed sensors to analyze sweat for multi-purpose diagnostics

- Ion or electrolyte measurement in body fluids like sweat, urine, saliva or blood
- Application in medicine
- Combination of analytes is possible (sensor multi-array) as well as combination with other sensors (ECG, body temperature, breathing etc.)
- Advantage of our solution:
  Determination of intra corporal states is non-invasive, real time, portable and cost-efficient
- Outlook:
  - Textile integrated hardware for real time analysis
  - Patent pending (July 2016)



© Fraunhofer IIS/Kurt Fuchs

Image Processing and Medical Engineering

Conclusions

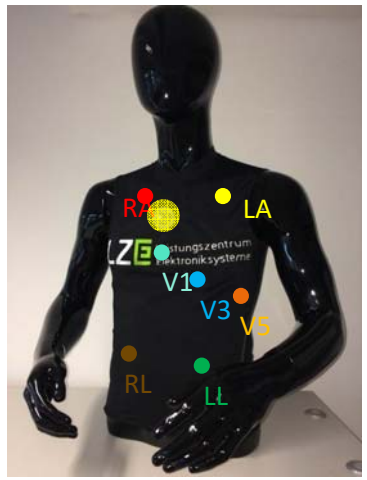
- Markets and perspectives for health-related consumer products and professional clinical-grade products are different
- Most market-available health-related wearable products are addressing consumers and fail to meet serious user requirements
- Clinical-grade wearable products
  - must meet extended regulatory frameworks
  - require integration of wearables, services and intelligence
  - are expected to establish an emerging, promising market
- Health-related / medical products based on wearables are drivers towards future human-centric assistance and healthcare
- Textile integration can contribute to success of future wearable solutions addressing health-related / professional use-cases

Image Processing and Medical Engineering

Conclusions (2)

- Textile integration can contribute to success of wearable solutions addressing health-related / medical use-cases ➔ clinical grade wearables

EnableYourWear



METEAN

Fraunhofer IIS

Image Processing and Medical Engineering

Contact

Christian Weigand

Head of department
Image Processing and Medical Engineering

Fraunhofer Institute for Integrated Circuits IIS
Am Wolfsmantel 33
91058 Erlangen, Germany

Phone +49 9131 776-7300
E-Mail christian.weigand@iis.fraunhofer.de

www.metean.de
www.iis.fraunhofer.de/med

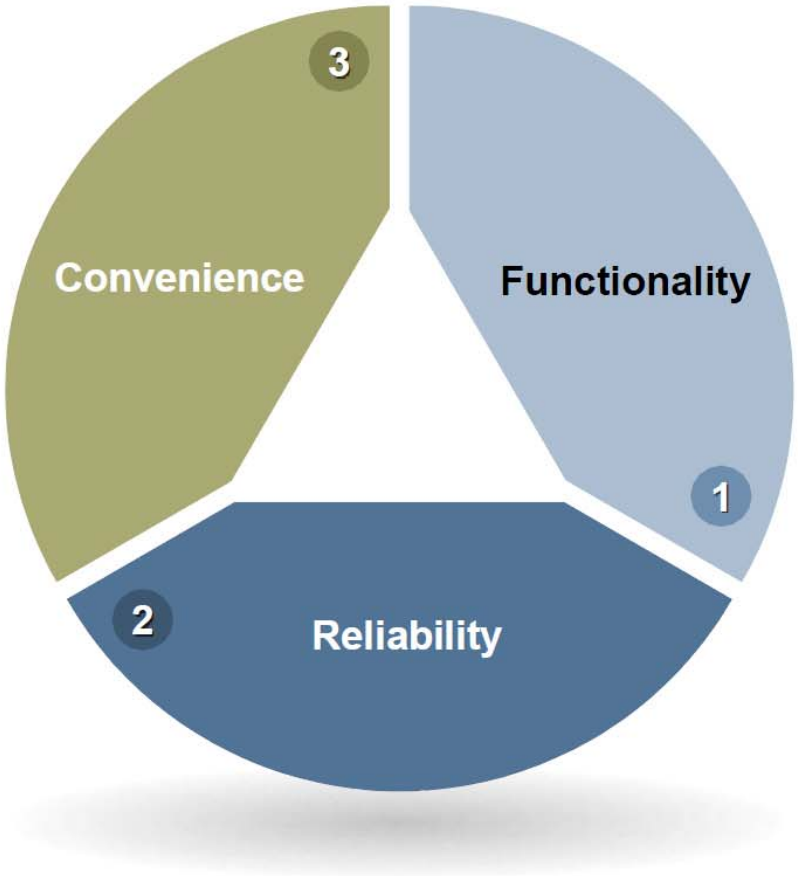
METEAN

Fraunhofer IIS

Anhang

Future Healthcare Wearables

3 Essential Considerations for Development



1. Should collect health vitals and other physiological factors that are potentially valuable for individuals and health professionals.
   - Create services and solutions to make the output more actionable.
2. Wearables should accurately measure and validate essential individual health information (API-based population health benchmarking).
   - Compliance with industry gold standards for clinical validation (e.g., FDA approval, CE mark).
3. Design wearable devices that are passive, comfortable, and provide positive reinforcement to the user.
   - Continuously update the offering by leveraging technological advancements in the component and service space to ensure convenience.

Source: Frost & Sullivan

METEAN

Fraunhofer IIS

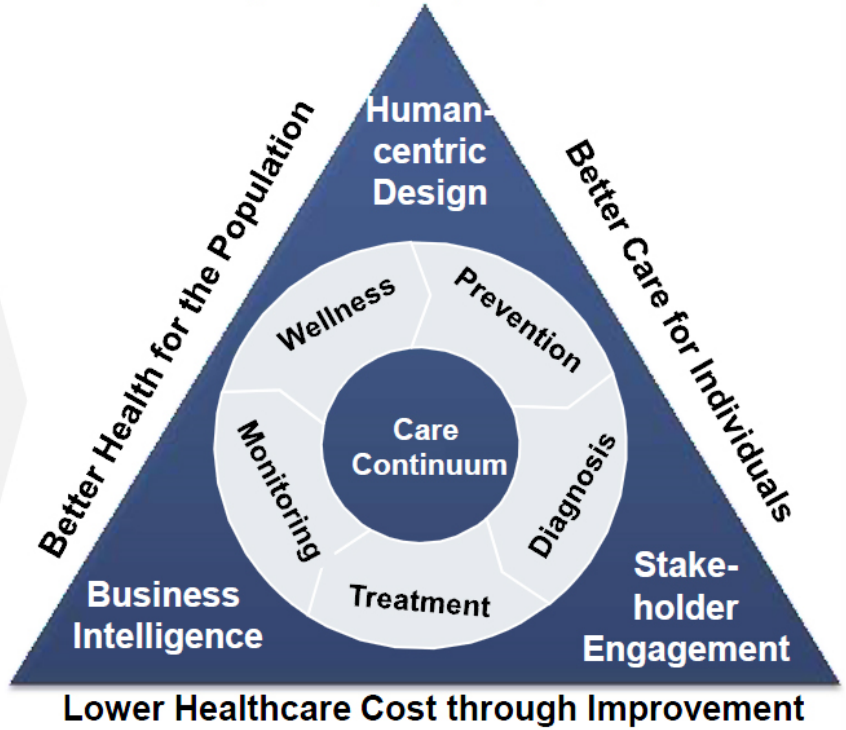
Steps Towards Patient-Centric Care Delivery

Enabling Patient-Centric Care

2015	2020	2025
Phase 1	**Phase 2**	**Phase 3**
• Deployment and project management services around wearable devices • Awareness and behavior modification by education and training	• Real-time data management and analytics platforms • Integration of population health data to derive personalized insights • Design wearable devices around services	• eVisits (clinical and user support) • User coordination (including care) • Data interpretation and display • Wearables on PaaS & DaaS models
Activation & Adoption	**Core Monitoring**	**Broader Applications**

Key: PaaS —Product As a Service; DaaS—Data as a Service

Healthcare Wearables Segment: Device and Service Implementation Phases for Customer-Centric Care Delivery, Global, 2015, 2020, and 2025



Source: Pwc; Frost & Sullivan

METEAN

Fraunhofer IIS

Links

- http://www.heise.de/newsticker/meldung/Kommentar-Wearables-Betriebssystem-Baut-lieber-bessere-Smartwatches-2151142.html
- http://www.heise.de/newsticker/meldung/Intel-steigt-mit-Uebernahme-in-den-Markt-fuer-Wearables-ein-2155152.html
- http://www.heise.de/newsticker/meldung/Crowdfunding-Knapp-3-4-Millionen-US-Dollar-fuer-smarte-Ohrhoerer-2158406.html
- http://www.heise.de/newsticker/meldung/Von-neuen-Wearables-Selbstironie-und-Spielverderbern-2159492.html
- http://www.heise.de/mac-and-i/meldung/Studie-Smartwatch-Markt-noch-unterentwickelt-2161980.html
- http://www.heise.de/newsticker/meldung/Fitbit-fuer-alte-Menschen-schlaegt-bei-Notfaellen-Alarm-2139702.html
- http://www.heise.de/newsticker/meldung/Bostoner-Aerzte-testen-Google-Glass-im-Klinikalltag-2141112.html
- http://www.heise.de/newsticker/meldung/Pulsmesser-im-Ohr-2138979.html
- http://www.heise.de/newsticker/meldung/Kommentar-Fitness-Wearables-sind-das-Gegenteil-von-Freiheitsberaubung-2136979.html
- http://www.golem.de/news/sensoren-spuert-die-iwatch-sonnenlicht-und-gesten-1404-105694.html
- http://www.golem.de/news/wearables-selbst-gemacht-mit-nadel-faden-und-3-volt-1404-105307.html

Wearables 2017

- **Top 10 Strategic Technology Trends for 2017 (Gartner)**
  - Artificial Intelligence and Advanced Machine Learning
  - Intelligent Apps
  - Intelligent Things
  - Virtual Reality and Augmented Reality
  - Digital Twins
  - Blockchains and Distributed Ledgers
  - Conversational Systems
  - Mesh App and Service Architecture
  - Digital Technology Platforms
  - Adaptive Security Architecture

Wearables 2017

- Smartwatches still for early tech adopters (10 percent)
- Fitness trackers reach early mainstream (19 percent)
- VR glasses / Head-Mounted Displays (8 %)
- "Dropout from device usage is a serious problem for the industry," said Angela McIntyre, research director at Gartner. "The abandonment rate is quite high relative to the usage rate. To offer a compelling enough value proposition, the uses for wearable devices need to be distinct from what smartphones typically provide. Wearables makers need to engage users with incentives and gamification."
- (The 2016 Gartner Personal Technologies Study surveyed 9,592 online respondents from Australia, the U.S. and the U.K. between June and August 2016)

Measuring ions and electrolytes in sweat, urine, saliva and blood

- ELECSA (by Fraunhofer IIS)

Electronics

- Small hand held device for sensor evaluation
- Bluetooth Smart compatible microcontroller module
- High impedance analog front end
- CR2032 coin cell battery
- Android application for recording and evaluation of sensor data

Summary

- Biosensor fulfilling requirements for non-specialist application[1)]
  - accurate, precise, reproducible and linear over the concentration range of interest
  - real-time analysis
  - cheap, small, portable and capable of being used by semi-skilled operators
- Outlook:
  - Textile integrated hardware for real time analysis

Images: Fraunhofer IISB

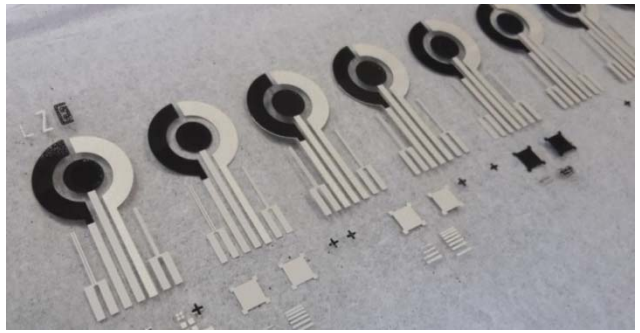
Images: Fraunhofer IIS (Fuchs)

1) D. Grieshaber, Sensors 8 (2008) p. 1401

ELECSA

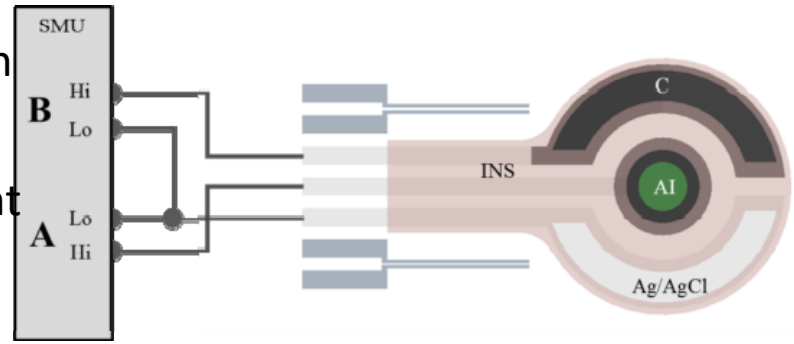
Technology

- Printed electrodes:
  - Working electrode: Silver (Ag), carbon (C)
  - Ion-selective membrane: Ionophore in carrier matrix
  - Reference electrode: Ag / AgCl



printed sensor electrodes, Van der Pauw test structures

- Electromotive Force (EMF)
  - Difference of potentials depending on ion concentration
  - Currentless, potentiometric measurement with a high internal resistance of source meter



Images: Fraunhofer IISB

METEAN

Fraunhofer IIS

Sophisticated printed sensors to analyze sweat for multi-purpose diagnostics

Service Portfolio

- Building of prototypes with your specifications
- Chaperoning patient studies in cooperation with clinics
- Long standing competence in development of medical technologies and medical devices
- Patent application for ELECSA July 2016

© Fraunhofer IIS/Kurt Fuchs