Where are we going?

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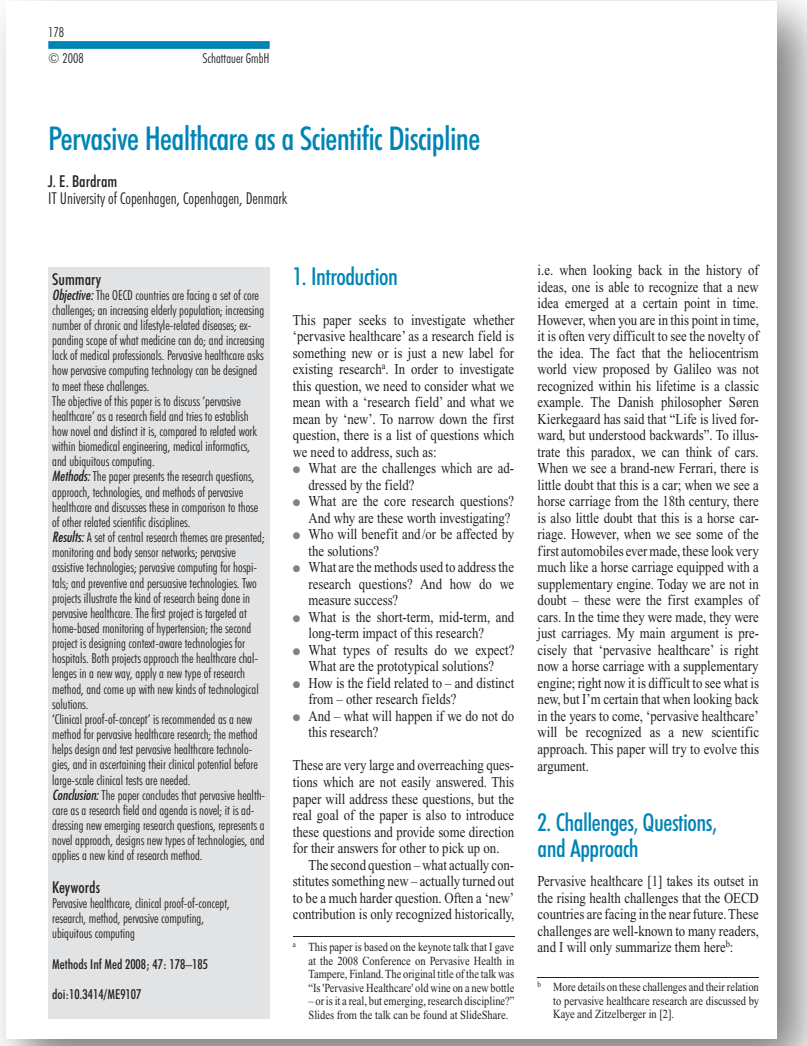
UNIVERSITY OF COPENHAGEN

Major Trends

Acute	→	Continuous
Hospitalization	→	Ambulatory & Home
Reactive	→	Pro-active & Preventive
Information Tech	→	Health Technology
Centralized	→	Pervasive
Sampling	→	Monitoring
Doctor-centric	→	Patient-centric



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Pervasive Healthcare as a Scientific Discipline

J. E. Bardram
IT University of Copenhagen, Copenhagen, Denmark

Summary

Objective: The OECD countries are facing a set of core challenges; an increasing elderly population; increasing number of chronic and lifestyle-related diseases; expanding scope of what medicine can do; and increasing lack of medical professionals. Pervasive healthcare asks how pervasive computing technology can be designed to meet these challenges.
The objective of this paper is to discuss 'pervasive healthcare' as a research field and tries to establish how novel and distinct it is, compared to related work within biomedical engineering, medical informatics, and ubiquitous computing.
Methods: The paper presents the research questions, approach, technologies, and methods of pervasive healthcare and discusses these in comparison to those of other related scientific disciplines.
Results: A set of central research themes are presented; monitoring and body sensor networks; pervasive assistive technologies; pervasive computing for hospitals; and preventive and persuasive technologies. Two projects illustrate the kind of research being done in pervasive healthcare. The first project is targeted at home-based monitoring of hypertension; the second project is designing context-aware technologies for hospitals. Both projects approach the healthcare challenges in a new way, apply a new type of research method, and come up with new kinds of technological solutions.
'Clinical proof-of-concept' is recommended as a new method for pervasive healthcare research; the method helps design and test pervasive healthcare technologies, and in ascertaining their clinical potential before large-scale clinical tests are needed.
Conclusion: The paper concludes that pervasive healthcare as a research field and agenda is novel; it is addressing new emerging research questions, represents a novel approach, designs new types of technologies, and applies a new kind of research method.

Keywords
Pervasive healthcare, clinical proof-of-concept, research, method, pervasive computing, ubiquitous computing

Methods Inf Med 2008; 47: 178–185

doi:10.3414/ME9107

1. Introduction

This paper seeks to investigate whether 'pervasive healthcare' as a research field is something new or is just a new label for existing research[a]. In order to investigate this question, we need to consider what we mean with a 'research field' and what we mean by 'new'. To narrow down the first question, there is a list of questions which we need to address, such as:

- What are the challenges which are addressed by the field?
- What are the core research questions? And why are these worth investigating?
- Who will benefit and/or be affected by the solutions?
- What are the methods used to address the research questions? And how do we measure success?
- What is the short-term, mid-term, and long-term impact of this research?
- What types of results do we expect? What are the prototypical solutions?
- How is the field related to – and distinct from – other research fields?
- And – what will happen if we do not do this research?

These are very large and overreaching questions which are not easily answered. This paper will address these questions, but the real goal of the paper is also to introduce these questions and provide some direction for their answers for other to pick up on.

The second question – what actually constitutes something new – actually turned out to be a much harder question. Often a 'new' contribution is only recognized historically, i.e. when looking back in the history of ideas, one is able to recognize that a new idea emerged at a certain point in time. However, when you are in this point in time, it is often very difficult to see the novelty of the idea. The fact that the heliocentrism world view proposed by Galileo was not recognized within his lifetime is a classic example. The Danish philosopher Søren Kierkegaard has said that "Life is lived forward, but understood backwards". To illustrate this paradox, we can think of cars. When we see a brand-new Ferrari, there is little doubt that this is a car; when we see a horse carriage from the 18th century, there is also little doubt that this is a horse carriage. However, when we see some of the first automobiles ever made, these look very much like a horse carriage equipped with a supplementary engine. Today we are not in doubt – these were the first examples of cars. In the time they were made, they were just carriages. My main argument is precisely that 'pervasive healthcare' is right now a horse carriage with a supplementary engine; right now it is difficult to see what is new, but I'm certain that when looking back in the years to come, 'pervasive healthcare' will be recognized as a new scientific approach. This paper will try to evolve this argument.

2. Challenges, Questions, and Approach

Pervasive healthcare [1] takes its outset in the rising health challenges that the OECD countries are facing in the near future. These challenges are well-known to many readers, and I will only summarize them here[b]:

[a] This paper is based on the keynote talk that I gave at the 2008 Conference on Pervasive Health in Tampere, Finland. The original title of the talk was "Is 'Pervasive Healthcare' old wine on a new bottle – or is it a real, but emerging, research discipline?" Slides from the talk can be found at SlideShare.

[b] More details on these challenges and their relation to pervasive healthcare research are discussed by Kaye and Zitzelberger in [2].

JE Bardram. Pervasive Healthcare as a Scientific Discipline. *Methods of Information in Medicine*, 3(47):129-142, 2008.

BACKGROUND

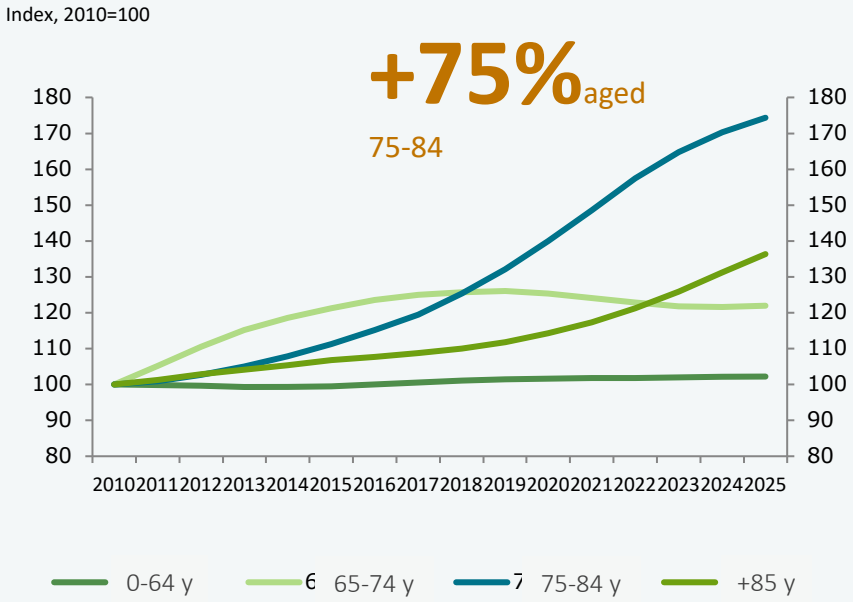
A change in our demography

The population is getting older

In 2025 the number of citizens aged 0-64 will be the same as in 2010.

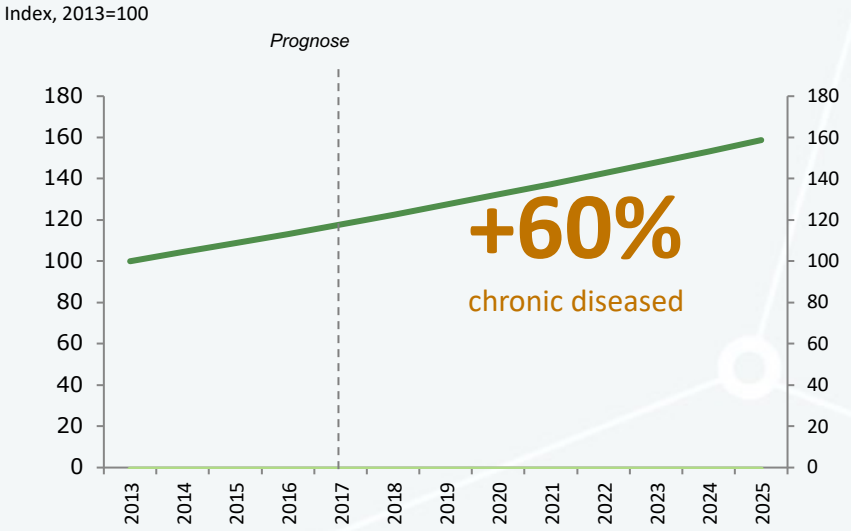
- but the number of citizens aged 75-84 will have increased by 75 percent.

→ Less tax payers and fewer health care workers



- and more people will suffer from chronic diseases

From 2013 to 2025 the number of citizens living with the most common chronic diseases is expected to increase by 60 pct.



Source: Digital Health Strategy 2018-2022, Danish Ministry of Health, 2018.

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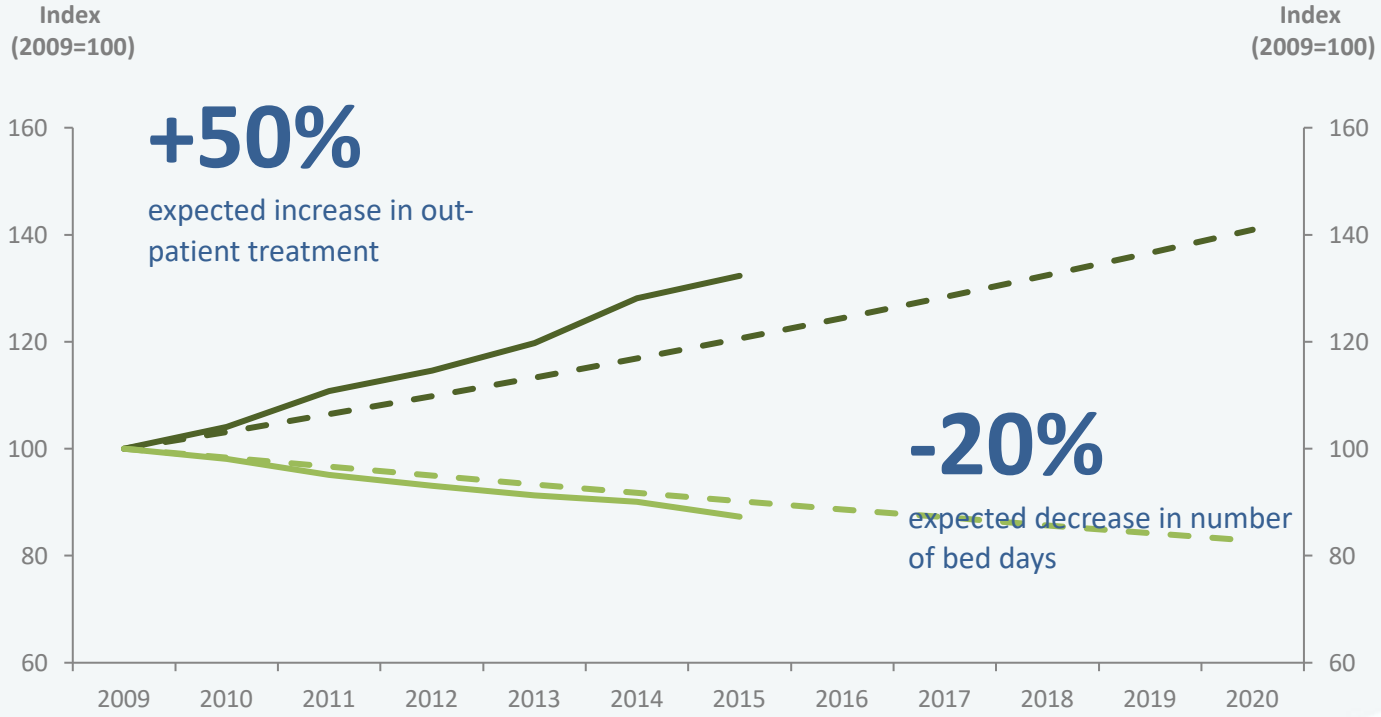
A change in hospitalisation and technology



businesswire
A BERKSHIRE HATHAWAY COMPANY

HOME SER

Venture Funding in Digital H
Billi

Telemedicine shatter

January 06, 2021 02:14 PM Eastern Standard Time

AUSTIN, Texas--(BUSINESS WIRE)--Mercom Capita
report on funding and mergers and acquisitions (M&

"The pandemic has mainstreamed the consumer side of digital health technologies in less than a year. Digital health products that were a novelty a year or two ago are now a necessity."

Tweet this

increased 278%, with $6.8 billion raised in 26 deals

GOOGLE TECH

Goog

The fitness

By Chaim Garten

Google The Keyword

Latest stories Product updates Company news

DEVICES & SERVICES

Google completes Fitbit acquisition

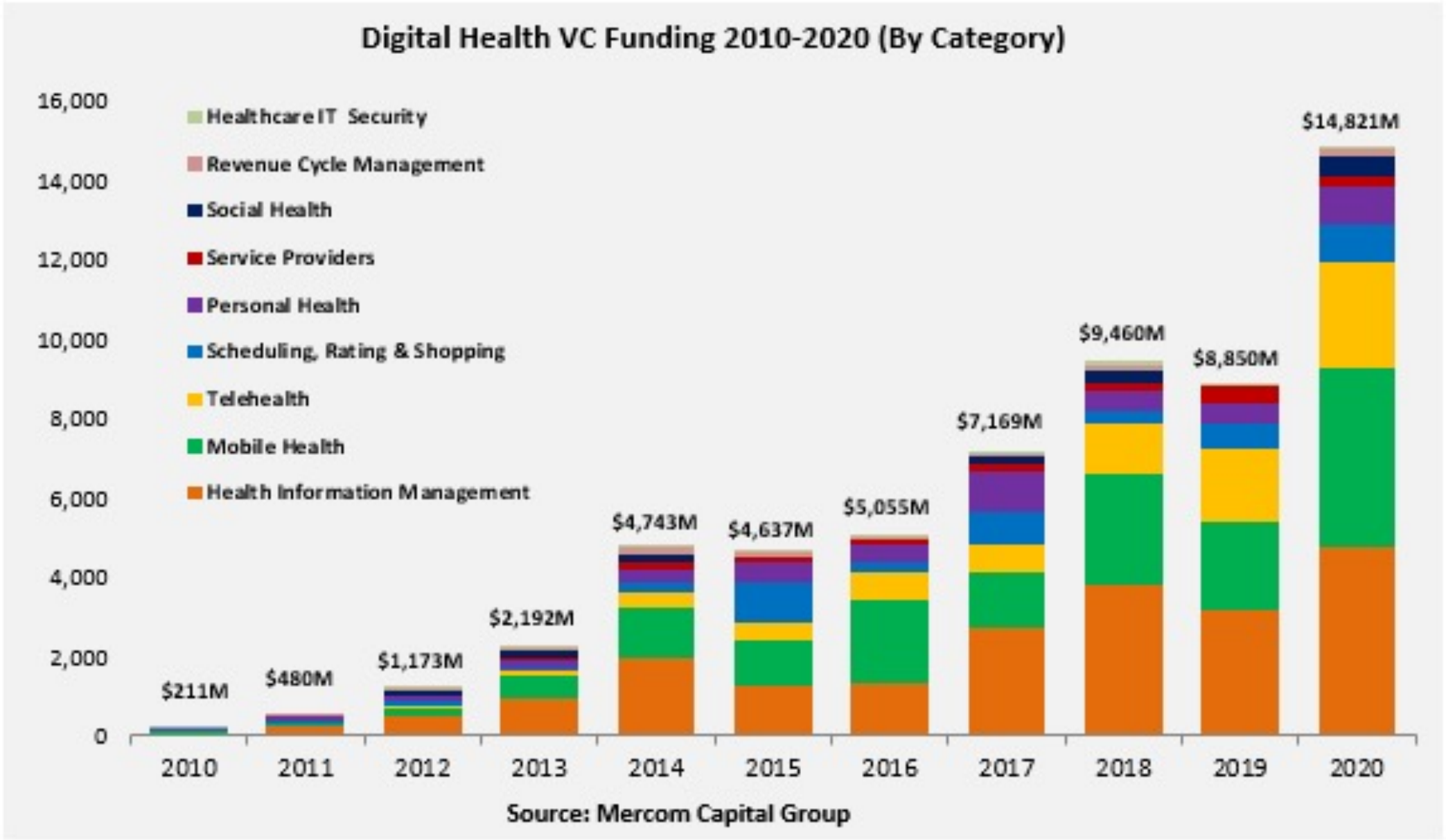
Rick Osterloh

Senior Vice President, Devices & Services

Published Jan 14, 2021

For more than a decade, Fitbit has helped people around the world live healthier, more active lives. A clear pioneer in the industry, Fitbit built a vibrant community of more than 29 million active users by creating amazing wearable devices and immersive wellness experiences. Today, I'm excited to announce that Google has completed its acquisition of Fitbit and I want to personally welcome this talented team to Google.

Fitbit's latest and most advanced health and fitness smartwatch, Fitbit Sense, features stress management tools and new ways to manage your heart health, including an ECG app to assess heart rhythm for signs of atrial fibrillation (AFib). And with its latest tracker, Inspire 2, Fitbit brought an enhanced design and features, including Active Zone Minutes, to its most accessible device. Fitbit added a


Digital Health VC Funding 2010-2020 (By Category)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Healthcare IT Security
Revenue Cycle Management
Social Health
Service Providers
Personal Health
Scheduling, Rating & Shopping
Telehealth
Mobile Health
Health Information Management
$211M
$480M
$1,173M
$2,192M
$4,743M
$4,637M
$5,055M
$7,169M
$9,460M
$8,850M
$14,821M
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Source: Mercom Capital Group

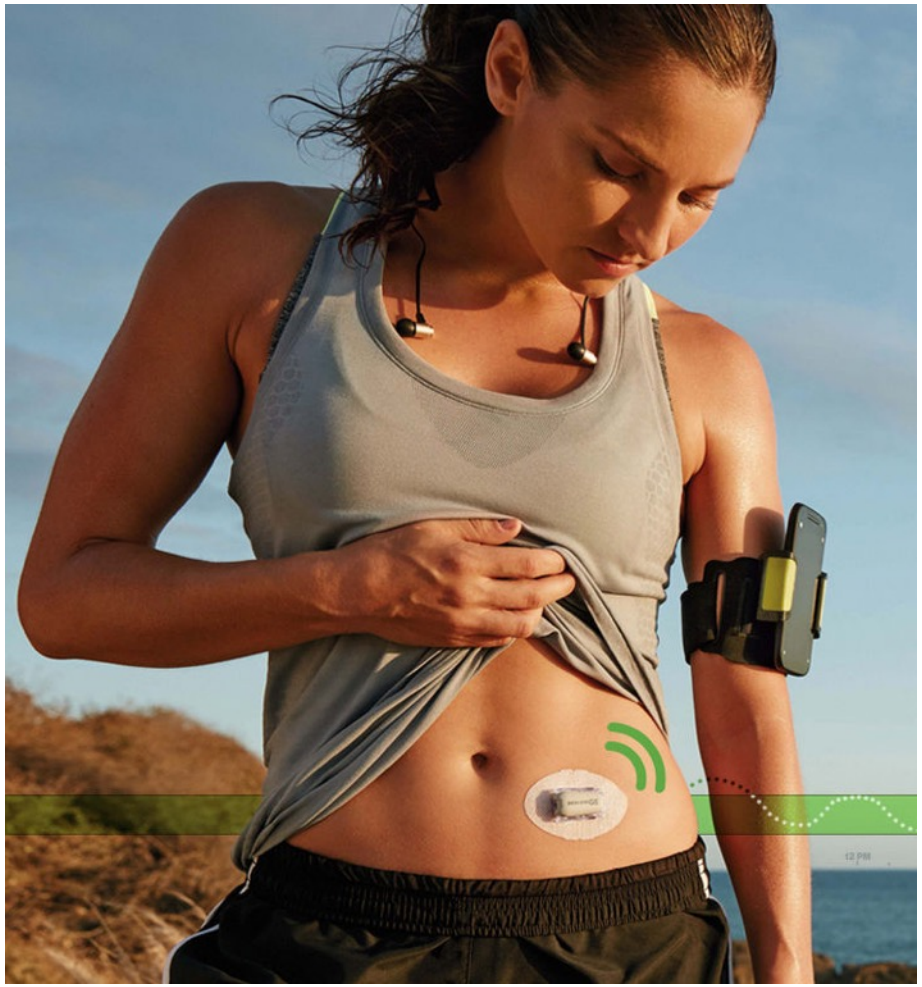
Withings

One Drop

- glucose monitor (strip based)
- 24/7 expert support
- mobile/watch apps

Dexcom G6 CGM

- Continuous Glucose Monitoring (CGM)
- SmartPhone / SmartWatch
- Alerts
- Sharing

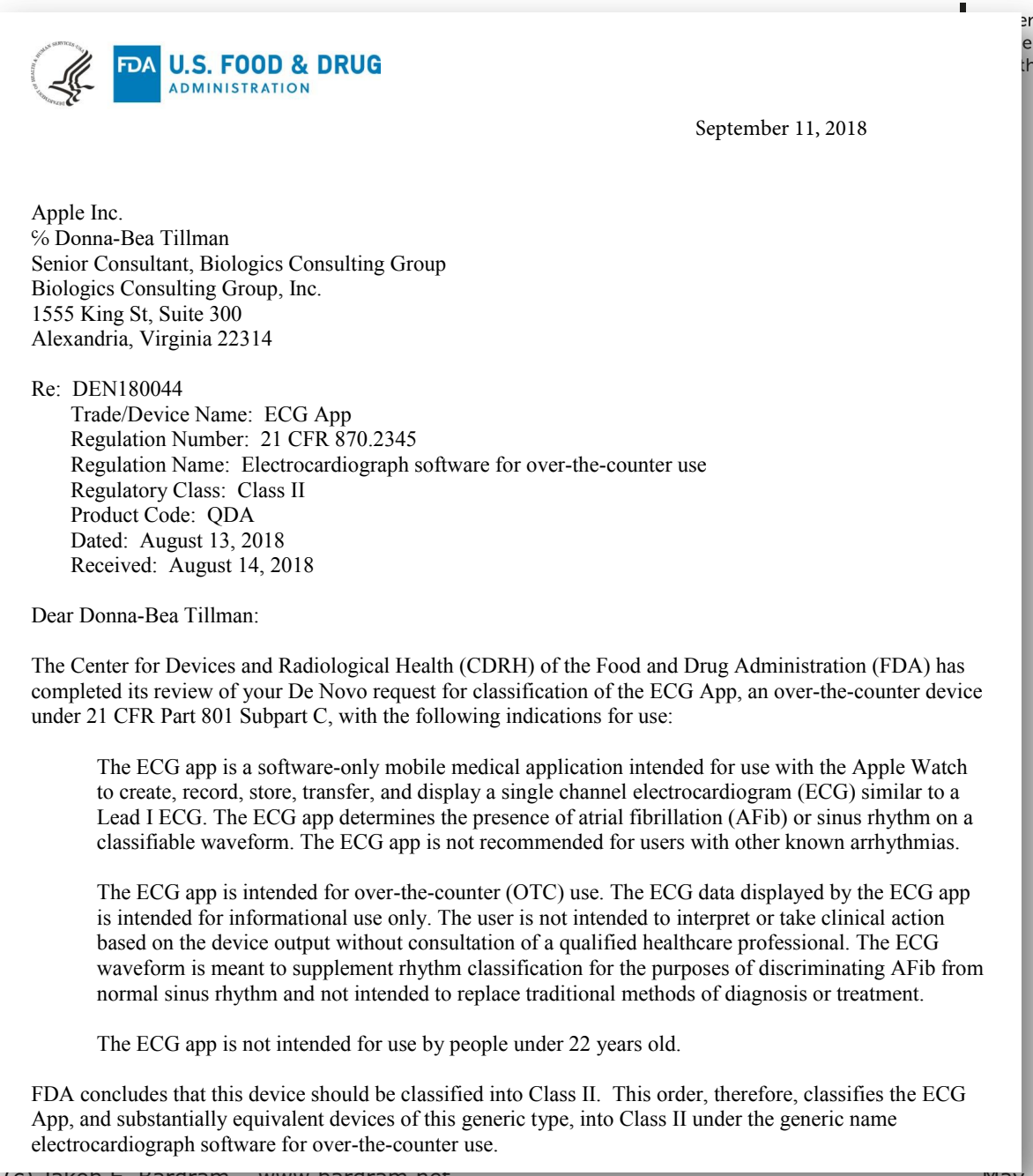


Definition of Personal Health Technology

- Two broad categories
  - –Professional Medical Devices
    - targeted a specific disease / health
    - 'prescribed' by doctors => customer == clinicians
    - strongly regulated – CE marked | FDA approved
  - –Wellness and Consumer Health Technologies
    - targeted general wellness and wellbeing
    - 'consumed' by end-users => customer == consumers
    - not regulated (CE | FDA)
- ... but the lines are *blurring*

Apple Watch s5

- Workout
  - move | exercise | stand
  - running | swimming | gym | ...
  - competing (social)
- Health
  - HR | HRV | ECG
  - AF detection
  - cycle | stress | noise
  - glucose | food | ...
  - fall detection | emergency



FDA U.S. FOOD & DRUG ADMINISTRATION

September 11, 2018

Apple Inc.
% Donna-Bea Tillman
Senior Consultant, Biologics Consulting Group
Biologics Consulting Group, Inc.
1555 King St, Suite 300
Alexandria, Virginia 22314

Re: DEN180044
Trade/Device Name: ECG App
Regulation Number: 21 CFR 870.2345
Regulation Name: Electrocardiograph software for over-the-counter use
Regulatory Class: Class II
Product Code: QDA
Dated: August 13, 2018
Received: August 14, 2018

Dear Donna-Bea Tillman:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its review of your De Novo request for classification of the ECG App, an over-the-counter device under 21 CFR Part 801 Subpart C, with the following indications for use:

> The ECG app is a software-only mobile medical application intended for use with the Apple Watch to create, record, store, transfer, and display a single channel electrocardiogram (ECG) similar to a Lead I ECG. The ECG app determines the presence of atrial fibrillation (AFib) or sinus rhythm on a classifiable waveform. The ECG app is not recommended for users with other known arrhythmias.
>
> The ECG app is intended for over-the-counter (OTC) use. The ECG data displayed by the ECG app is intended for informational use only. The user is not intended to interpret or take clinical action based on the device output without consultation of a qualified healthcare professional. The ECG waveform is meant to supplement rhythm classification for the purposes of discriminating AFib from normal sinus rhythm and not intended to replace traditional methods of diagnosis or treatment.
>
> The ECG app is not intended for use by people under 22 years old.

FDA concludes that this device should be classified into Class II. This order, therefore, classifies the ECG App, and substantially equivalent devices of this generic type, into Class II under the generic name electrocardiograph software for over-the-counter use.

How to Uber a Diabetes Business Before it Gets Kodak-ed (Digital Health Today 360°) LISTEN NOW

Roche Diabetes HEALTH CONNECTION

controlling costs for your business

RocheDiabetes Health Connection - Let's Talk Numbers

Let's Talk Numbers

Watch on YouTube

Presenting customized, all-in-o
support and remote moni

Population Management

Aggregated, real-time data from the entire patient population drives risk stratification.

Member Engagement

Includes the mySugr App, an Accu-Chek® Guide meter and unlimited supplies delivered at home.

Your C
of Coa

Let us provic
coaching s
provide y
caregivers wi
our platform
Coach on Y
Progr

ginger

How It Works | Ginger for Business | Resources | Our Company | CONTACT US

Behavio
coachin

Our behavioral health
support for life's chal
your anxiety or gettin
to wait for an appoint
support via text with
coach day or night, 3

60 seconds

Average time to connect with a coach

24 hours a day

Coaches available around-the-clock

Therapy & psychiatry

Licensed therapists and psychiatrists are available and can be added to your care team for sessions via video. Our behavioral health coaches, therapists and psychiatrists work together as a team. If needed, medication can be prescribed and managed by our psychiatrists, and delivered to your doorstep.*

Convenient

Same-day prescription delivery via Capsule in

7 days a week

Sessions available on weekends and evenings

Average rating for clinical sessions

FALCK

Sundhedspakker | Forebyggelse | Behandling | Hurtigt Rask

Virtuel Sundhed

SUNDHED FRA DISTANCEN - FOREBYGGELSE OG BEHANDLING

Med en samlet virtuel sundhedspakke fra Falck Healthcare kan du booste din virksomheds sundhed. Pakken bidrager via en række sundhedsfremmende tiltag til øget trivsel og produktivitet blandt medarbejderne på arbejdspladsen.

Forebyggelse

Forebyggende indsatser tilpasset til dig på din lokation om f.eks. ernæring, fysisk aktivitet og stress.

Korrekt behandling (digital)

Virtuel psykolog og fysioterapi, f.eks. angående udfordringer ved social isolation, rygsmerter, eller rådgivning omkring epidemirelaterede problemer.

- **Individuelle virtuelle konsultationer (video/telefon)** Psykolog, læge, fysioterapeut og ergonomisk rådgivning.
- **Virtuelle sundhedsevents (gruppesessioner)** Regelmæssige events, f.eks. skræddersyet træning med

Fordele for medarbejderen

- Direkte adgang til professionelt sundhedspersonale 24/7
- Nem adgang til virtuelle behandlinger og konsultationer
- Sjov og velvære i samvær med kollegaer i virtuelle gruppesessioner
- Motivation gennem selvtræning- og behandling

18-35%

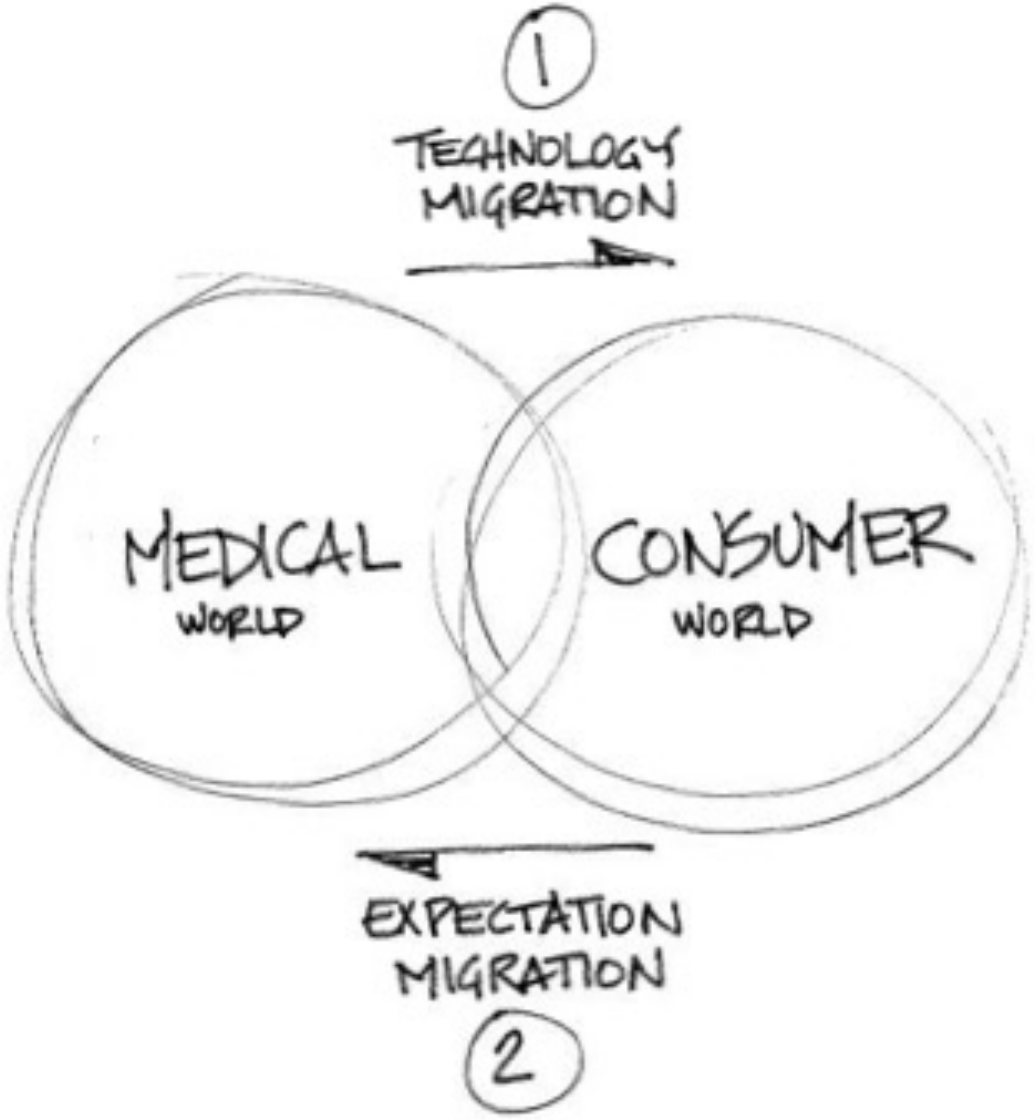
Stigning i skader relateret til hjemmearbejde under Covid-19.*

53%

Af medarbejdere siger, at de døjer med nakke- og skuldersmerter.

En nem og samlet løsning

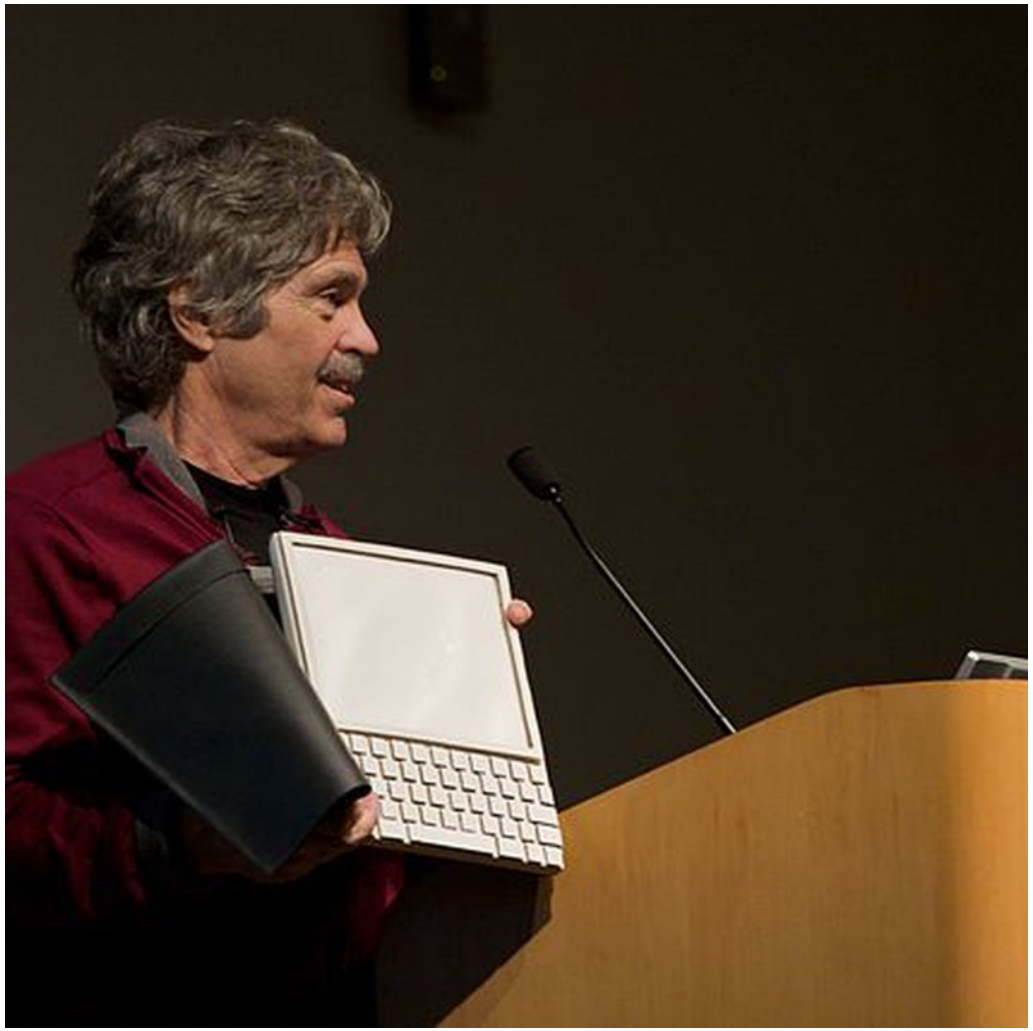
VEJEN TIL EN SUNDERE HVERDAG...


1
TECHNOLOGY MIGRATION
MEDICAL WORLD
CONSUMER WORLD
EXPECTATION MIGRATION
2


12.20-12.40
Hvor bevæger det digitale sundhedsvæsen sig hen?
v/ professor Jakob Bardram,
Danmarks Tekniske Universitet

“The best way to predict the future is to invent it”

Allan Kay



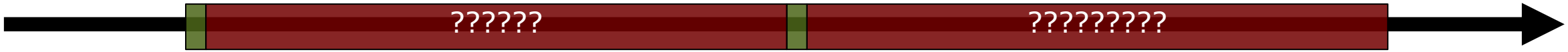
Main Findings from our Research

#1 – From passive to engaged citizens/patients

#2 – From reactive to proactive healthcare

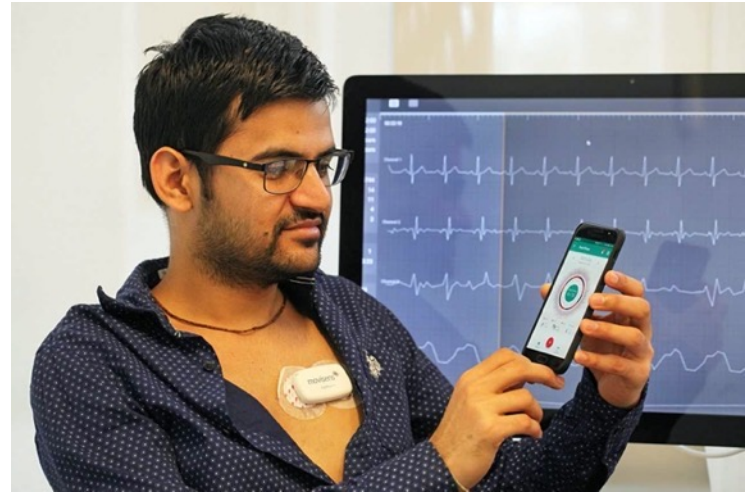
mCardia :: Detection of Atrial Fibrillation

- Cardiovascular diseases is the 1st cause of death and the 2nd leading disease burden (WHO)
- ECG monitoring is core to most CVD treatment
- Today
  - in-clinic monitoring for short period (10 min)
  - constrained Holter monitoring w. manual data upload
  - no knowledge on "context" (physiological, behavioral, medical, cognitive, mental, ...)
  - a manual labeling and detection process



mCardia: A Context-Aware System for Arrhythmia Screening

- Novel digital phenotyping technology for arrhythmia screening
  - **ambulatory** – data collection under free-living conditions
  - **longitudinal** – 2-5 weeks of data collection
  - **contextual** – behavior, environment, activity, self-reports
- 2 studies :: Denmark & India
  - N=24
  - high usability and user engagement scores
  - huge ambulatory dataset collected
  - patient annotation of experienced “events”



D Kumar, R Maharjan, A Maxhuni, H Dominguez, A Frølich, JE Bardram. " mCardia: A Context-Aware Ambulatory ECG Collection System for Arrhythmia Screening" To be published in *ACM Transaction on Computing for Health, 2021*.

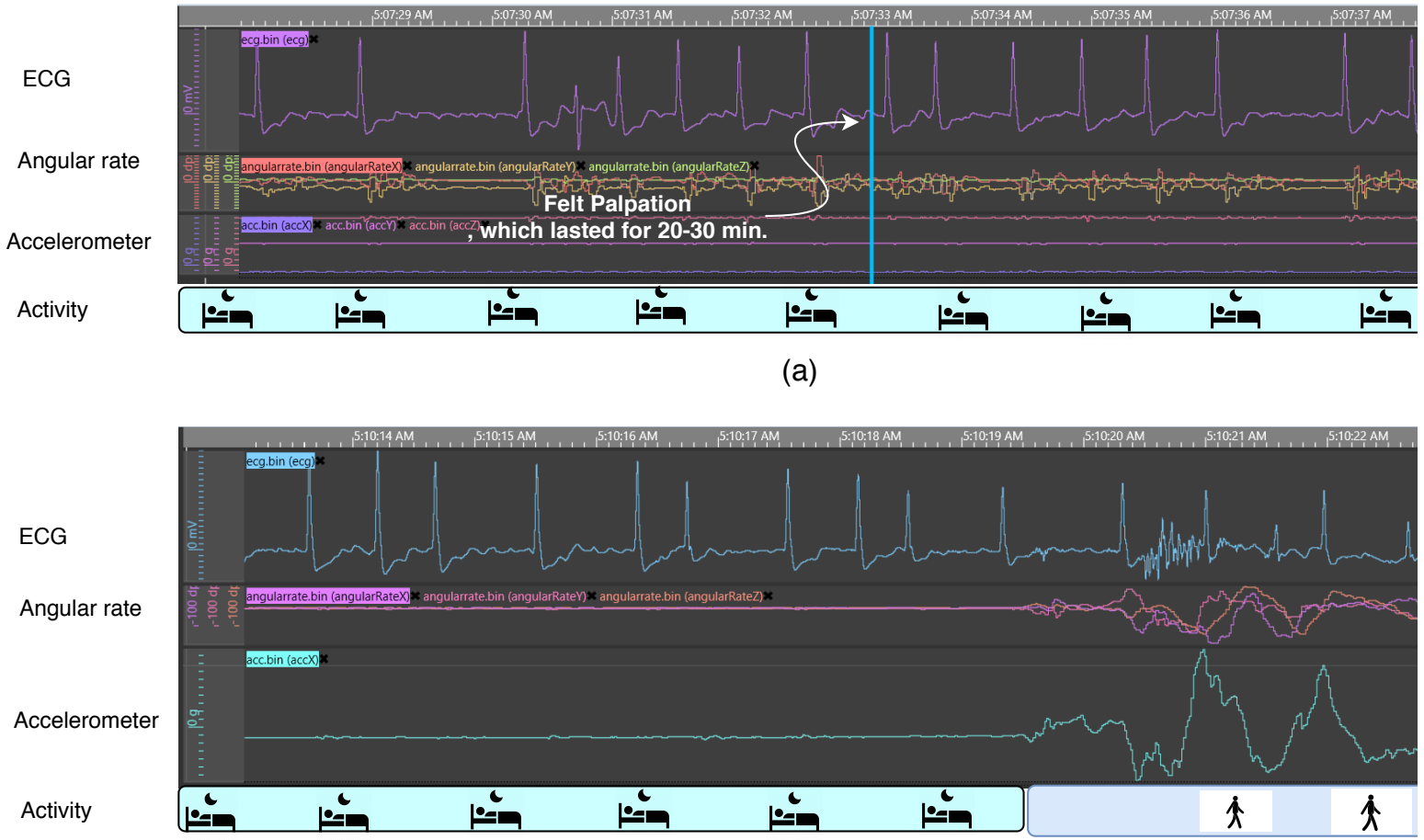


Fig. 12. Clinical case #2 demonstrating the usefulness of context information in medication prescription. (a) Subject tapped on device and registered an event. (b) Subject gets up from the bed and starts walking.

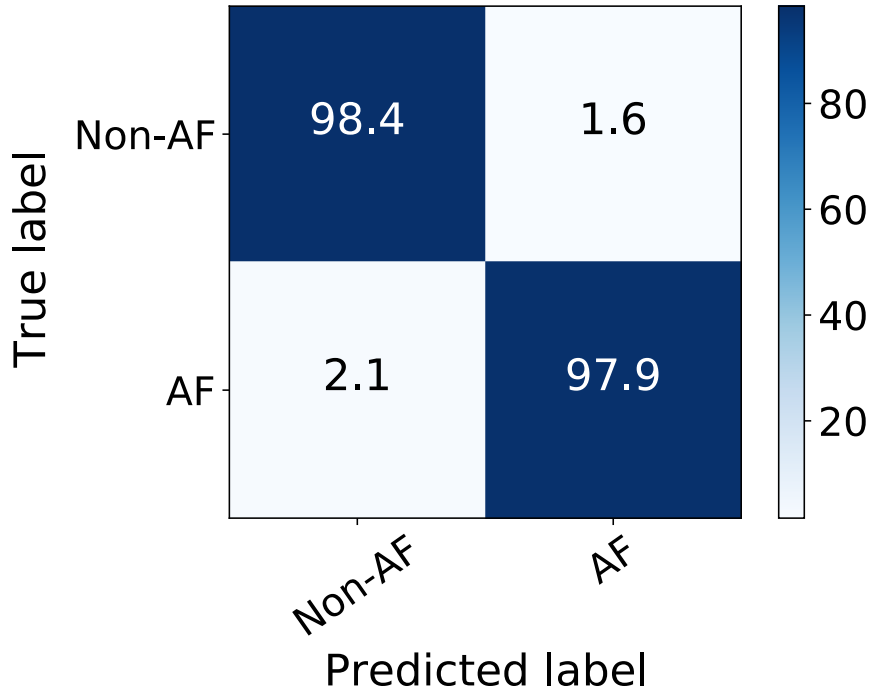
Reactive Healthcare Model

- Today
  - healthcare is reactive – initiated based on an "incident"
  - while most research shows that early intervention is crucial to most diseases

Deep-learning Method for Ambulatory AF Detection

- **"In-the-Wild"** real-time detection of atrial fibrillation
  - ambulatory, contextual data
  - patient-reported data
  - based on CACHET-CADB ("in-the-wild" data)
  - **98% accuracy**

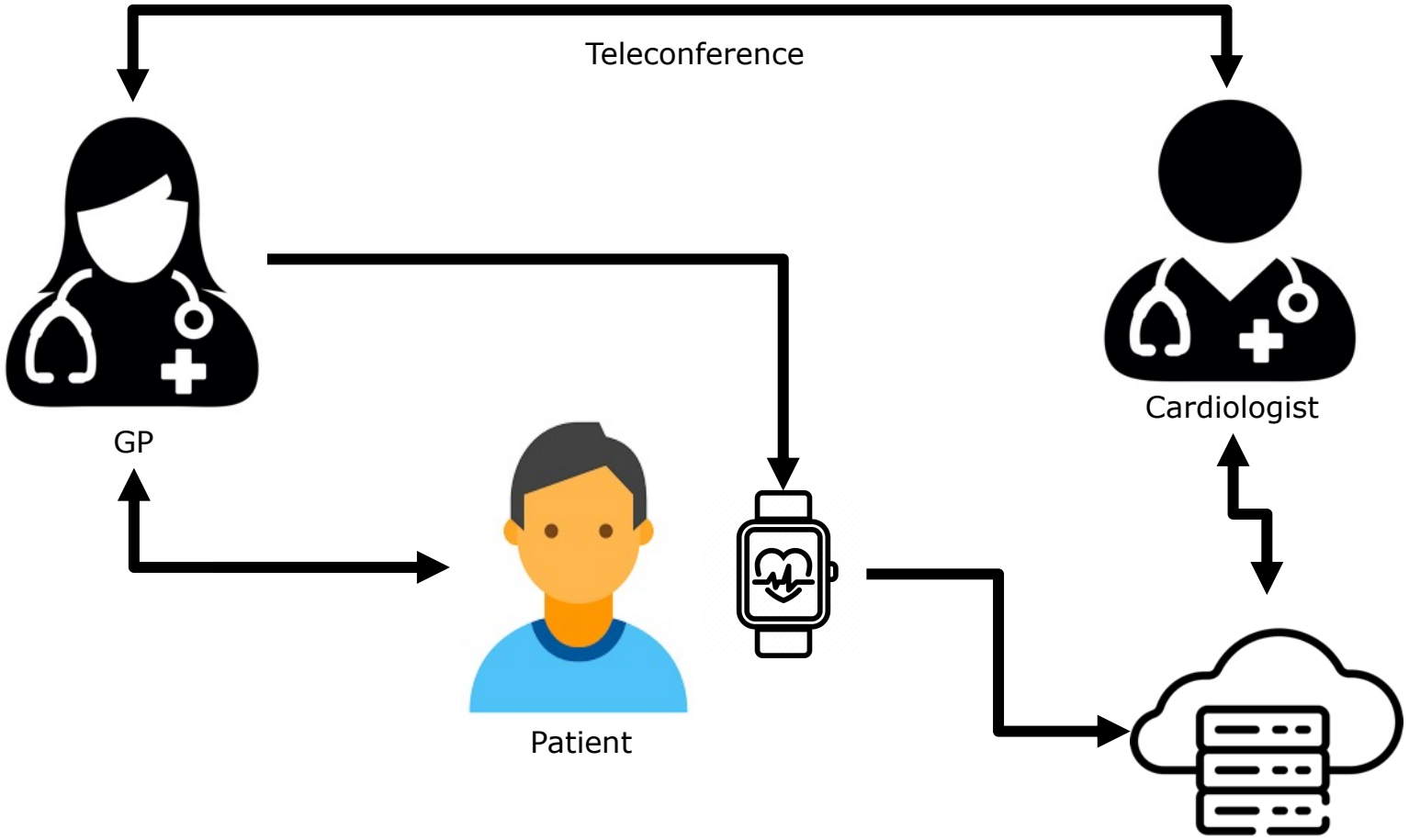
- Implications
  - reduction of **manual** Holter analysis
  - **pro-active** detection of AF
  - semi-automatic **triage**
  - early **intervention**



D Kumar, A Peimankar, K Sharma, H Dominguez, S Puthusserypady, and JE Bardram. "*DeepAware*: A Hybrid Deep Learning and Context-Aware Heuristics Based Model for Atrial Fibrillation Detection" Under review.

mCardia in the REAFEL project

Reaching the Frail Elderly Patient for optimizing diagnosis of atrial fibrillation

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Lægevagt
Disponering
98344

2 Main Findings

#1 – From passive to engaged citizens/patients

- personal health technology (and services) will explode
- prevention, diagnosis, treatment, & care
- citizens/patients will be much more engaged

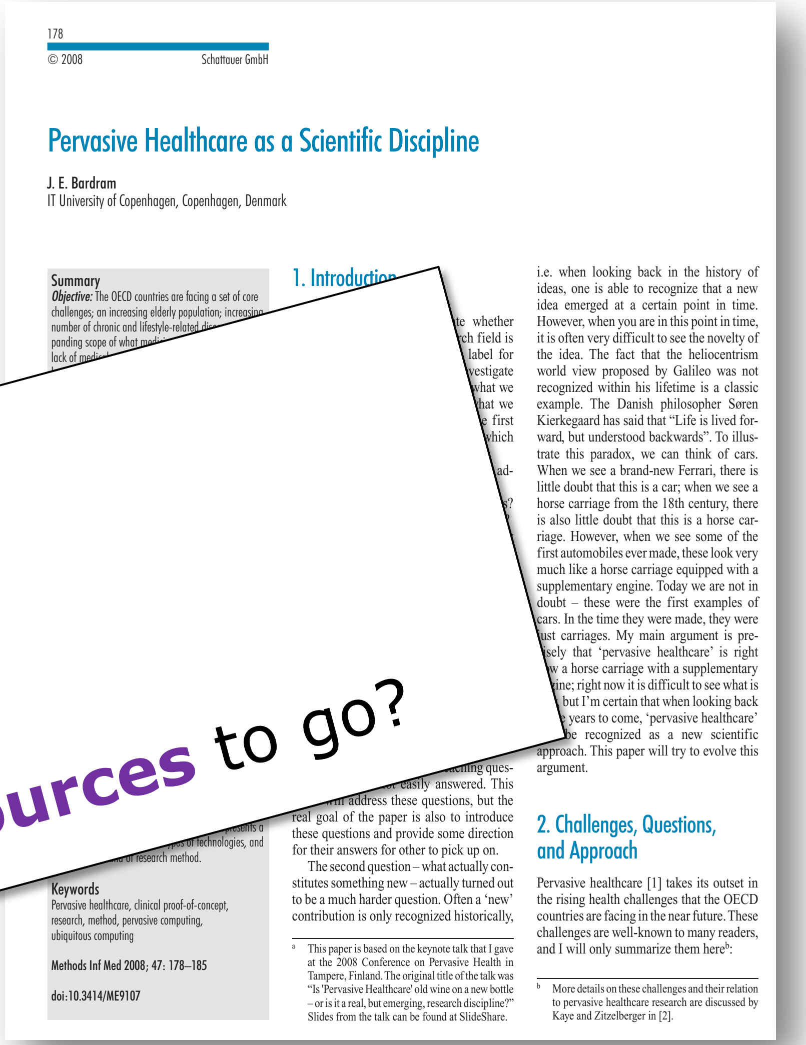
#2 – From reactive to proactive healthcare

- automated analysis, diagnosis & decision support
- data-based disease prediction
- triage & stratification leading to scalability

Major Trends & Strategic Decisions

Acute	→	Continuous
Hospitalization	→	Ambulatory & Home
Reactive	→	Pro-active & Preventive
Information Tech	→	Health Technology
Centralized	→	Pervasive
Sampling	→	Me…
Doctor-centric	→	

How far to the right
- do we **want** to go?
- can we **afford** to go?
- **should** we go?
- do we have the **resources** to go?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v/ professor Jakob Bardram,
Danmarks Tekniske Universitet

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bardram