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CENTER FOR WIRELESS & POPULATION HEALTH SYSTEMS

mHealth Research & Personal Health Data

Kevin Patrick MD, MS

Professor of Family Medicine and Public Health
Director, Center for Wireless and Population Health Systems
The Qualcomm Institute/Calit2
University of California, San Diego

Addressing ELSI Issues in Unregulated Health
October 9, 2017

UC San Diego

QUALCOMM INSTITUTE

it² Calit2

Center for Wireless and Population Health Systems

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Research on systems of wireless, clinical, and home technologies to measure and improve health-related exposures and behaviors in:

- -- Healthy adolescents
- -- Overweight and obese children and adults
- -- Depressed adults
- -- Adolescents risk for type 2 diabetes
- -- Adolescents with chronic disease (e.g. cystic fibrosis or IBD)
- -- Older adults to promote successful aging
- -- Adolescents recovering from leukemia
- -- Young adults to prevent weight gain
- -- Adults with schizophrenia
- -- Exposure biology & environmental health research
- -- Cancer comparative effectiveness research
- -- Individuals with TB in need of directly observed Rx

UC San Diego

Calit2

Collaborating Investigators & Partners

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UCSD School of Medicine
Family Medicine & Public Health, Pediatrics, Medicine, Psychiatry & Emergency Medicine
Kevin Patrick, MD, MS, Fred Raab, Linda Hill, MD, MPH, Jacqueline Kerr, PhD, Job Godino, PhD, Jeannie Huang, MD, MPH, Cheryl Rock, PhD, James Sallis, PhD, James Fowler, PhD, Lucila Ohno-Machado, MD, PhD, Richard Garfein, PhD, Ted Chan, MD, Cinnamon Bloss, PhD, Camille Nebeker, EdD

UCSD Jacobs School of Engineering, The Qualcomm Institute & The Design Lab
Bill Griswold, PhD, Tajana Rosing, PhD, Sanjoy Dasgupta, PhD, Yannis Papakonstantinau, PhD, Nadir Weibel, PhD, Jessica Block, MS, Don Norman, PhD

San Diego Supercomputer Center
Chaitan Baru, PhD

Qualcomm Institute
Natasha Balac, PhD, Marta Jankowska, PhD, Emilia Farcas, PhD

SDSU School of Public Health & Dept of Psychology
Elva Arredondo, PhD, Gregory Talavera, MD, MPH, Linda Gallo, PhD

PhD students and Post-doctoral Fellows (current) **Gina Merchant PhD, Maggie Crawford, Yannis Katsis, PhD, Max Menarino, PhD**

Funded by:

Robert Wood Johnson Foundation
NSF
National Heart Lung and Blood Institute
NIH OBSSR
NATIONAL CANCER INSTITUTE

Areas of research

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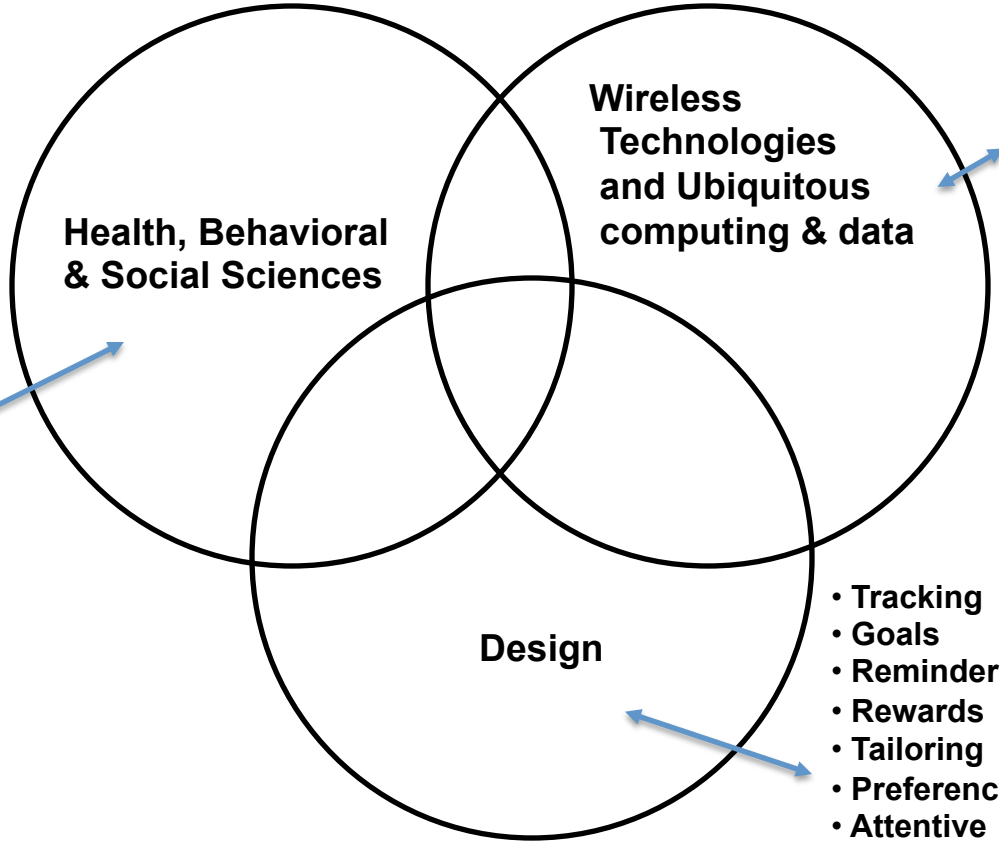


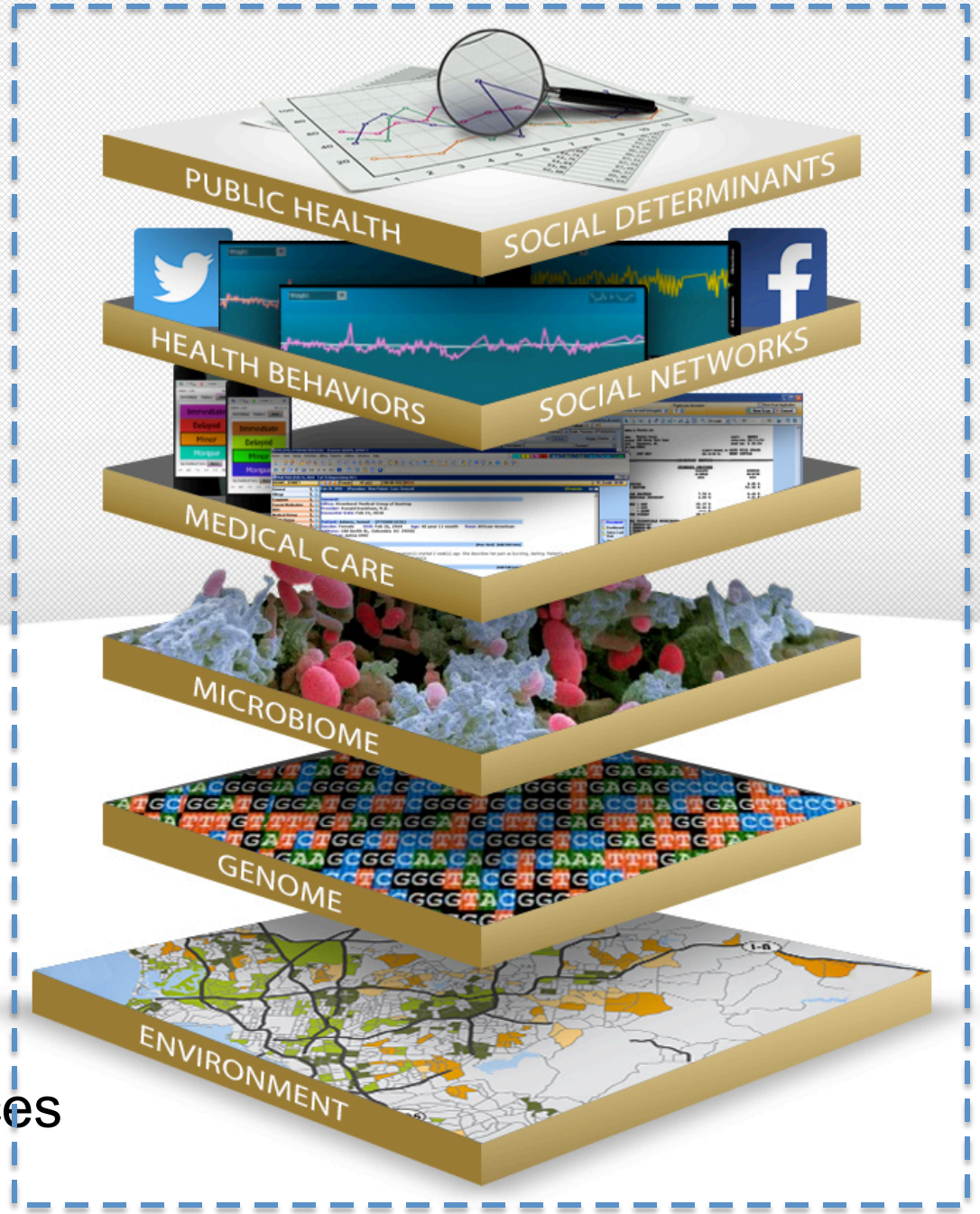
- Medical care
- Public health
- Personal health
- Social Networks

- Mobile phone apps
- SMS/MMS
- Mobile video
- Body area networks
- Wearable sensors
- Ecosystem of external sensors (home, work, etc.)
- Cloud computing
- Social networks
- Server analytics, data mining

- Tracking
- Goals
- Reminders
- Rewards
- Tailoring
- Preference-based
- Attentive
- Ecological
- Context Aware
- Gamified
- Cybernetic

- Cog Sci
- Media/Comm
- Beh Sci
- Soc Sci
- Hum/Comp Interaction

Mobile sensing technologies support connecting the dots….



Major influences on health

The Exposome

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Editorial

Complementing the Genome with an "Exposome": The Outstanding Challenge of Environmental Exposure Measurement in Molecular Epidemiology

Christopher Paul Wild

Molecular Epidemiology Unit, Centre for Epidemiology and Biostatistics, Leeds Institute of Genetics, Health and Therapeutics, Faculty of Medicine and Health, University of Leeds, Leeds, United Kingdom

Cancer Epidemiology, Biomarkers & Prevention

2005;14(8):1847-50

The Exposome

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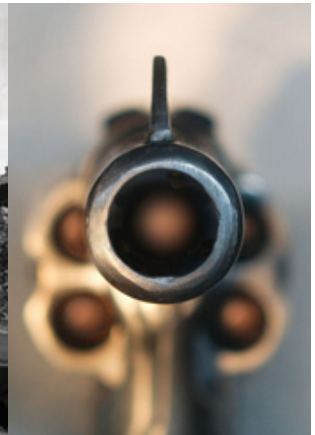
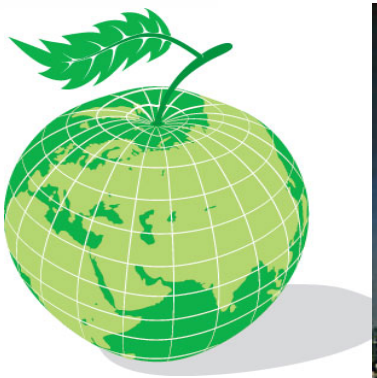
"At it's most complete, the exposome encompasses life-course environmental exposures (including lifestyle factors), from the prenatal period onwards…"

-- Christopher Paul Wild





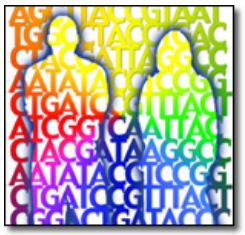
NIH Exposure Biology Program

"Genes load the gun; environment pulls the trigger" – Francis Collins, MD, PhD

2007	2008	2009	2010	2011

Environmental Sensors

- Diet/Physical Activity
- Chemicals/Biologics
- Psychosocial Stress/Addictive Substances

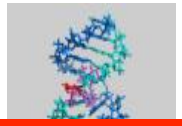


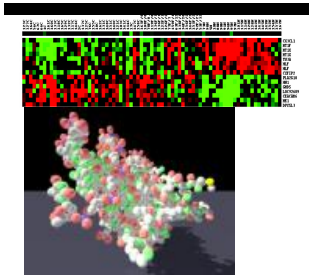
APPLICATION

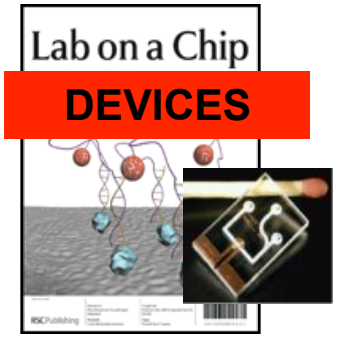
Genome Wide Association & Other Research

Biological Response

- Biomarkers
- Centers–biomarkers/biosensors
  - Inflammation
  - Oxidative stress
  - Programmed cell death
  - Epigenetic markers







How can mobile devices and related technologies enhance research?

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Greater precision on measures of physiological parameters that can aid in monitoring treatments, treatment response and outcomes.

Wireless and/or wearable sensors for:

- **Heart rate and heart rate variability**
- **Respiration**
- **Blood pressure**
- **Glucose, lactate & electrolytes**
- **Hydration & metabolism**
- **Medication adherence via smart pills, pill bottles and other drug delivery (e.g. inhalers)**
- **Spirometry**

How can mobile devices and related technologies enhance research?

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Greater precision on measures of behaviors and related health states and their context

Wireless and/or wearable sensors for:

- **Physical activity, sedentary behavior, and overall movement patterns that have unique signatures for underlying disease or health risk (e.g. Parkinson's, fall risk, etc.)**
- **Diet through self-report with always-available apps or with cameras**
- **Weight (and with BP, hydration status)**
- **Stress**
- **Sleep**
- **Cognitive function**
- **Location via GPS and other mobile phone-based approaches**

Importance of Place to Health

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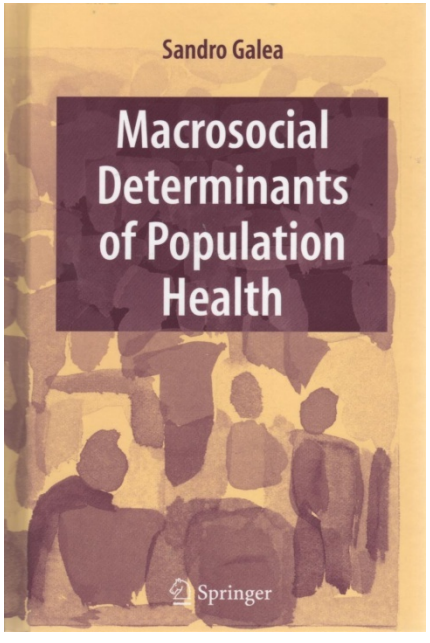
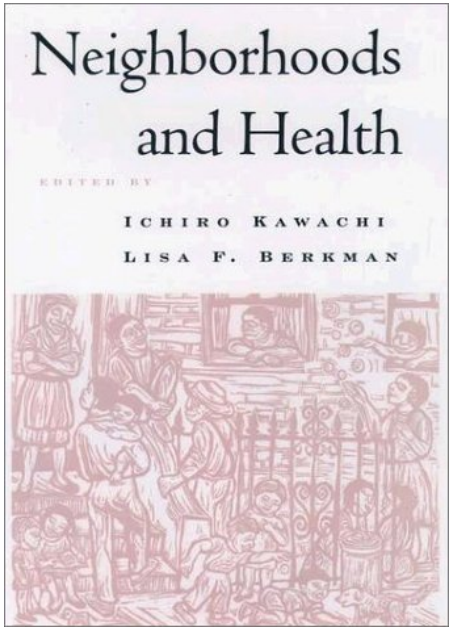
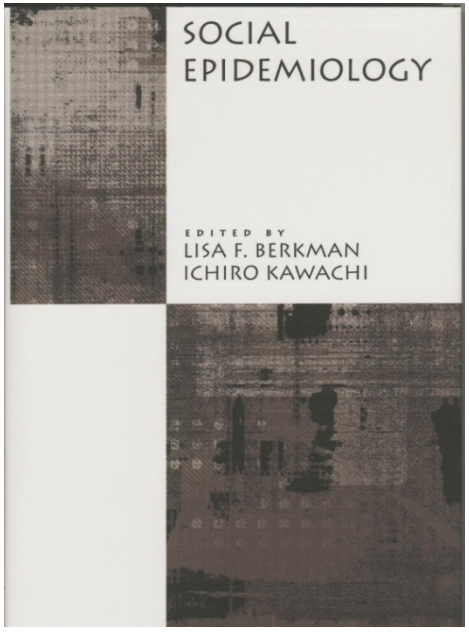
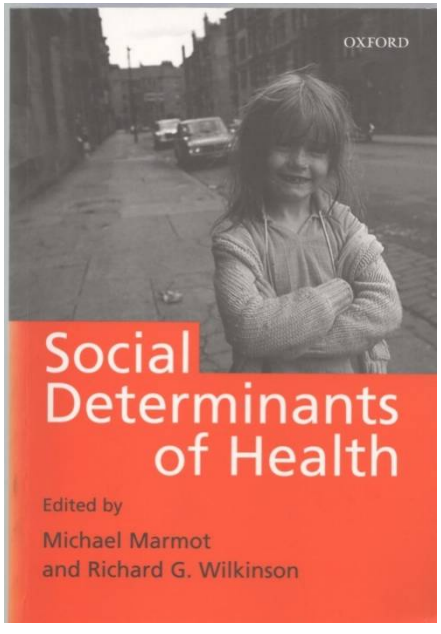
- Disease clusters
- Toxic exposure
- Health disparities
- Stress & incivilities







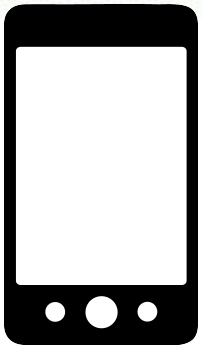


GPS Data & Geographic Information Systems (GIS) data

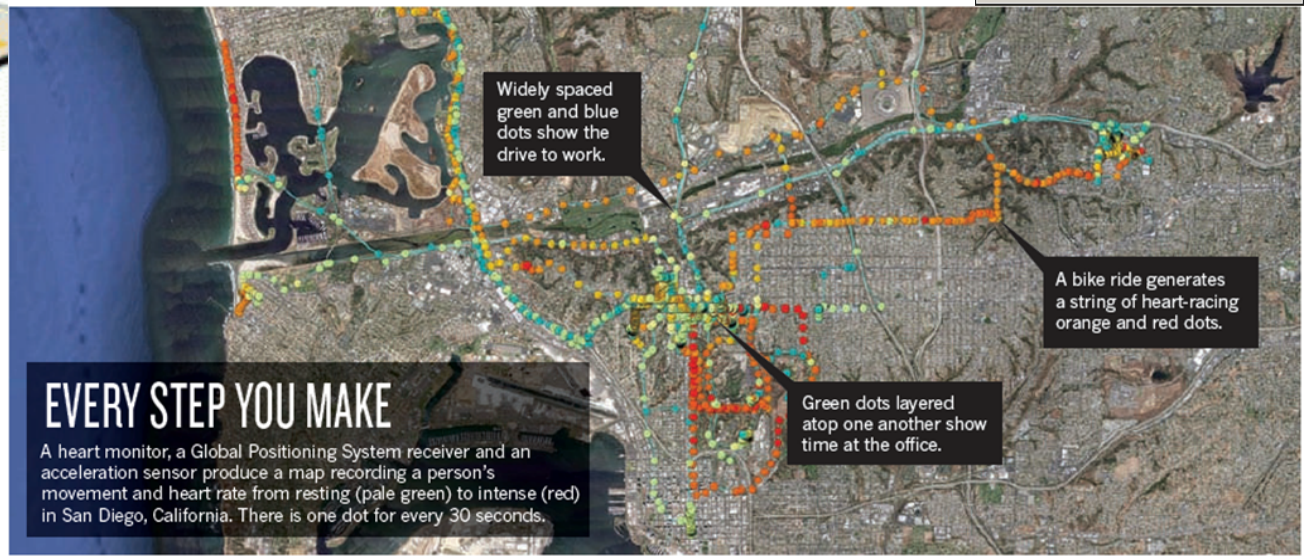
- **Parks**
  - **Distance & density & acreage**
- **Schools**
  - **Distance & density**
- **Recreation Facilities**
  - **Distance & density**
- **Census data**
  - **Housing unit density**
- **Parcel & Land Use**
  - **Commercial, industrial, institutional, residential, office, open space, vacant**
  - **Retail parcel count**
- **CoStar / SD County Tax Assessor**
  - **Retail floor area ratio**
- **Coastline**
  - **Distance to coast**
- **Local & Major Roads**
  - **Intersection & cul-de-sac counts**

Feb 16, 2011

NEWS FEATURE



GPS & other location detection technologies from Mobile Phone



How can mobile devices and related technologies enhance research?

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Greater precision on measures of experience and subjective states through Ecological Momentary Assessment (EMA), the use of a mobile device to query participants as events happen

EMA:

- **Is highly configurable to the underlying research question(s)**
- **Can be preset or automatically prompted based upon context (e.g. GPS)**
- **Can be intensive on an App, or "light" via quick-response text messages**
- **Can be offered in any language and at multiple levels of literacy and numeracy**

How can mobile devices and related technologies enhance research?

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Greater precision on measures of social interactions via online social networks, searches and other technologies such as sound, cameras, location and context

ELSEVIER

American Journal of Preventive Medicine

Volume 44, Issue 5, May 2013, Pages 520–525

Research and practice methods

Seasonality in Seeking Mental Health Information on Google

John W. Ayers, PhD, MA[a, c], Benjamin M. Althouse, ScM[d], Jon-Patrick Allem, MA[b], J. Niels Rosenquist, MD, PhD[f], Daniel E. Ford, MD, MPH[e]

BMJ

Twitter=quitter? An analysis of Twitter quit smoking social networks

Judith J Prochaska,[1] Cornelia Pechmann,[2] Romina Kim,[1] James M Leonhardt[2]

[1]Department of Psychiatry, University of California San Francisco, San Francisco, California, USA
[2]Paul Merage School of Business, University of California Irvine, Irvine, California, USA

ABSTRACT
Objective Widely popular, Twitter, a free social networking and micro-blogging service, offers potential for health promotion. This study examined the activity of Twitter quit smoking social network accounts.
Design A cross-sectional analysis identified 153 activated Twitter quit smoking accounts dating back to

called 'tweets', which have a maximum of 140 characters. Transmitted nearly instantaneously, tweets are received by 'followers' of the account on their mobile phones, email and/or personal Twitter websites. Created in 2006, Twitter membership has grown to >100 million users worldwide.[4] In June

facebook

Google

twitter

Instagram

How can mobile devices and related technologies enhance research?

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Greater precision on measures of environmental exposures such as particulate matter, noise, electromagnetic fields, environmental toxins & other insults that might impact such things as oxidative stress, immune response, hormonal regulation or other phenomena.

- **Wearable sensors that can store or transmit to/through the mobile phone data on exposures**
- **Combining data from wearable sensors with that from fixed sources in the Environment to enrich the understanding of cumulative exposure**
- **Periodic EMA & other triggered measurement tailored to specific research questions, or such things as occupation, location, natural disaster, or other Circumstance that might influence the natural course of treatment and/or outcomes**

A powerful combination

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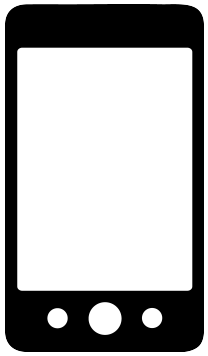
Smartphones and a wearable such as a Smartwatch

- Movement (accel/gyro)
- GPS
- Ecological Momentary Assessment (EMA)
- Voice/Sound
- Image
- Bluetooth connectivity to other devices
- Specialized apps

Carried as usual



- Movement (accel/gyro)
- Light EMA via SMS, etc.
- Heart rate/HR variability
- Specialized apps

Worn 24x7

MD2K Center of Excellence for Mobile Sensor Data-to-Knowledge

Advancing biomedical discovery and improving health through mobile sensor big data

Cornell Tech ♦ Georgia Tech ♦ U. Memphis ♦ Northwestern ♦ Ohio State ♦ Open mHealth ♦ Rice ♦ UCLA ♦ UC San Diego ♦ UC San Francisco ♦ UMass Amherst ♦ U. Michigan

Collecting High-frequency Mobile Sensor Data for Long-lasting Research Utility

Santosh Kumar

Director, MD2K Center of Excellence

Professor & Lillian and Morrie Moss Chair of Excellence

Department of Computer Science, University of Memphis


CORNELL NYC TECH
UCLA
Georgia Institute of Technology
UMASS AMHERST
UCSF University of California San Francisco
THE UNIVERSITY OF MEMPHIS
Open mHealth
THE UNIVERSITY OF MEMPHIS
UCLA
Computer Science
UNIVERSITY OF MICHIGAN
MD2K Center of Excellence for Mobile Sensor Data-to-Knowledge
Medicine
Behavioral Health
NORTHWESTERN UNIVERSITY
OHIO STATE
Electrical Engineering
RICE
OHIO STATE
UCLA
UC San Diego

MD2K Multidisciplinary Team – 20 investigators

Data Science Research

- Santosh Kumar, ***Memphis*** **(PI)**
- Gregory Abowd, Polo Chau, and Jim Rehg, ***Georgia Tech***
- Emre Ertin, ***Ohio State***
- Deborah Estrin, ***Cornell Tech***
- Tyson Condie, Mani Srivastava, ***UCLA***
- Deepak Ganesan, Ben Marlin, ***UMass***
- Susan Murphy, ***Harvard***

Health Research

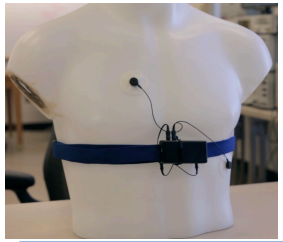
- William Abraham, ***Ohio State***
- Inbal Nahum-Shani, ***Michigan***
- Bonnie Spring, ***Northwestern***
- Cho Lam, Dave Wetter, ***Utah***
- Vivek Shetty, ***UCLA***
- Ida Sim, ***UC San Francisco***
- Jaqueline Kerr, ***UC San Diego***
- Clay Marsh, ***West Virginia***

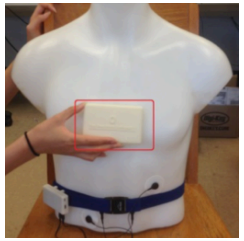
Memphis-based headquarter hosts a team of 10 grad students, a postdoc, 3 software engineers, and 6 staff members

Measuring Exposures, Behaviors, and Outcomes

Mobile Sensors

Smartwatch





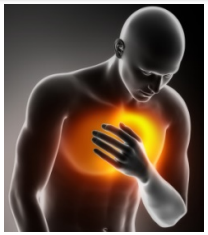
Chestbands

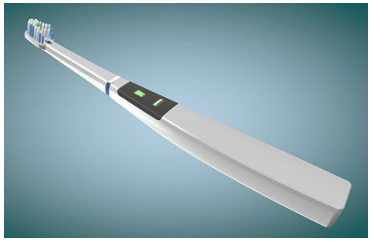
Smart Eyeglasses

Exposures

Behaviors

Outcomes





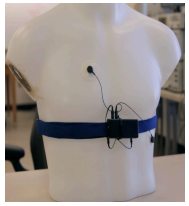
MD2K Center of Excellence for Mobile Sensor Data-to-Knowledge

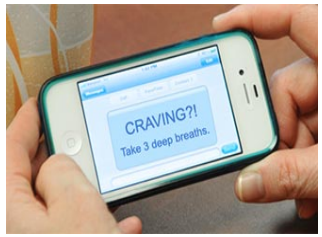
Advancing biomedical discovery and improving health through mobile sensor big data

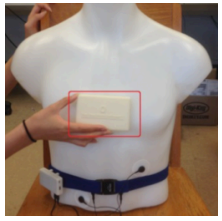
Cornell Tech ♦ Georgia Tech ♦ U. Memphis ♦ Northwestern ♦ Ohio State ♦ Open mHealth
Rice ♦ UCLA ♦ UC San Diego ♦ UC San Francisco ♦ UMass Amherst ♦ U. Michigan ♦ WVU

MD2K Applications – Smoking Cessation & CHF

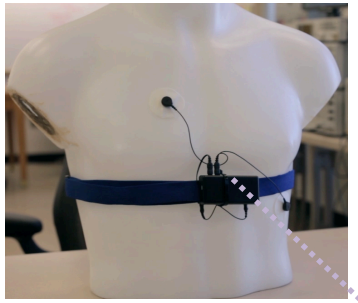
Detect → Predict → Adapt

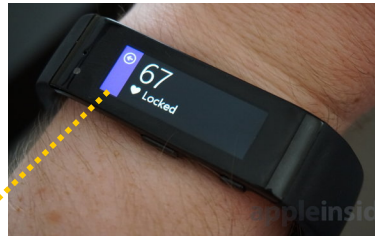


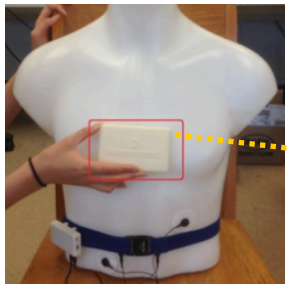
Mobile Sensor Data Sources in MD2K



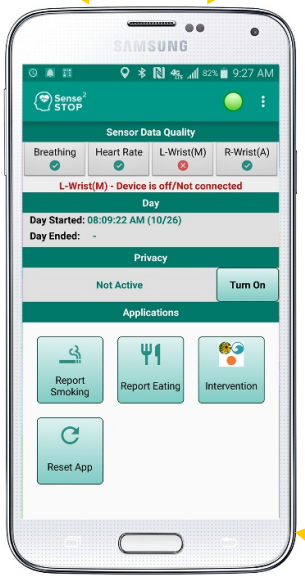
AutoSense sensors: ECG, respiration, accelerometers



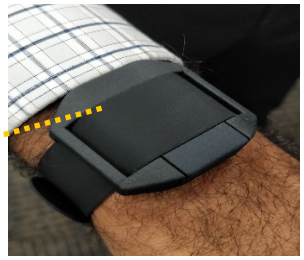
Microsoft Band:
accelerometers, gyroscopes, HR



EasySense (contactless) sensors: heart motion, lung motion, lung fluid level



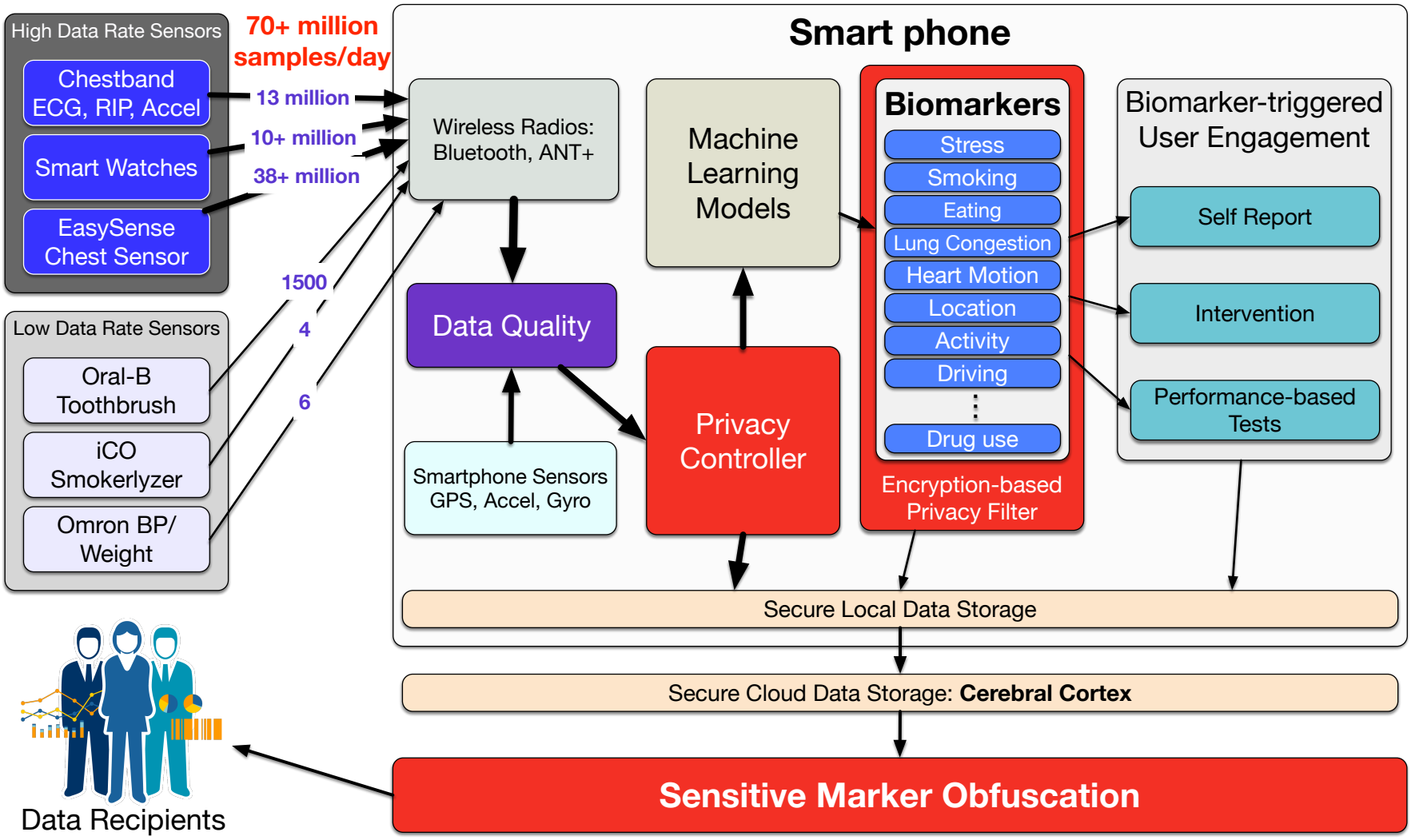
Smartphone sensors: GPS, accelerometers, self-report



MotionSense HRV:
accelerometers, gyroscopes, PPG

Smart toothbrush:
brushing, Pressure

MD2K Mobile Software Platform (open-source)



Health Data Exploration Project

Project Director: Kevin Patrick, MD, MS
Professor, Family and Preventive Medicine, UCSD
Director, Center for Wireless and Population Health Systems, Calit2

Project Co-Director, Jerry Sheehan, MA
Chief of Staff, Calit2

Investigators

Matthew Bietz, PhD, Project Scientist, UC Irvine
Judith Gregory, PhD, Adjunct Professor, UC Irvine
Scout Calvert, PhD, Project Scientist, UC Irvine
Ramesh Rao, PhD, Director, Calit2/UCSD

PI: K. Patrick
Co-Is: M. Bietz, C. Bloss
2013-2017

Robert Wood Johnson Foundation

The Internet of Things

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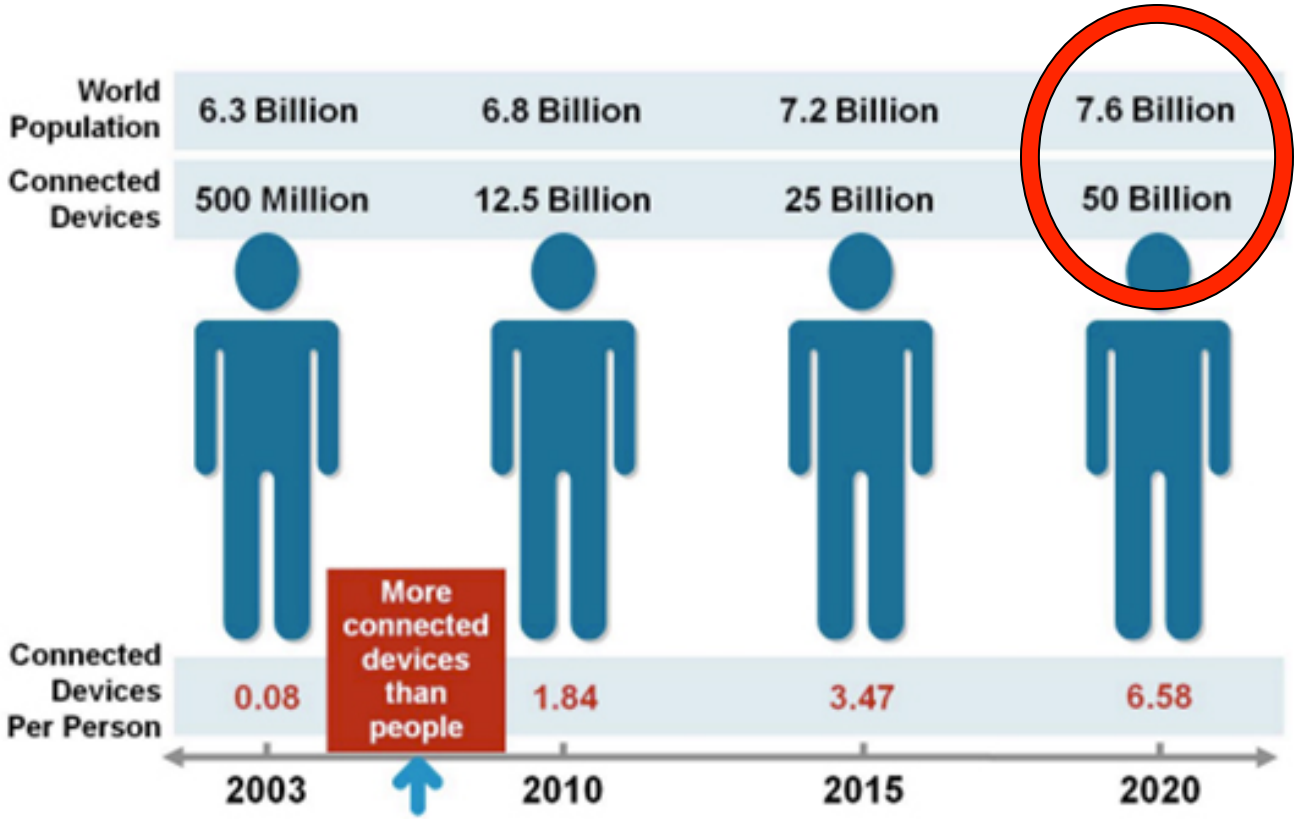

Source: Cisco IBSG, April 2011

Digital traces of everyday life…

An increasingly diverse & expanding ecosystem of devices, apps, and services generating vast amounts of data…

myfitnesspal
Calorie Counter & Diet Tracker

RunKeeper

mood

CVSHealth

Ralphs rewards

Google Microsoft IBM amazon.com

Issues (some)

- Research Methods (design, data, scale, etc.)
- Data Quality (validity, reliability)
- Representativeness of Data
- Data ownership & Terms of Use
- Privacy
- Ethics & Informed Consent
- Cultural differences (.com, .edu, .gov, .org)
- Dynamic nature of personal health data environment

Health Research Data Comparison

Clinical Data		Personal Data
Clinical Research Study	Context of Collection	Everyday Life
Expensive	Cost per Observation	Cheap
Validated	Measurement Trueness	Unvalidated
Tuned to Research Qs	Data Specificity	General Purpose
Standardized	Comparability	Unstandardized
Comprehensive	Completeness	Erratic
Personal, Clear	Informed Consent	Mediated, Questionable
Definable	Ethical Issues	Ambiguous
Highly Regulated	Confidentiality	Varies Widely
Low Risk of Identification	Anonymity	Larger Risk of Identification
Contrived	Ecological Validity	Lived Experience
Periodic	Pace of Observation	Continuous
Self-report	Behavior, Mood, Exposome	Sensed

Personal Data for the Public Good

New Opportunities to Enrich Understanding of Individual and Population Health

FINAL REPORT OF THE HEALTH DATA EXPLORATION PROJECT
FEBRUARY 2013

Health Data Exploration project

Health Data Exploration Project

Project Director: Kevin Patrick, MD, MS
Professor, Family and Preventive Medicine, UCSD
Director, Center for Wireless and Population Health Systems, Calit2

Project Co-Director, Jerry Sheehan, MA
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Investigators

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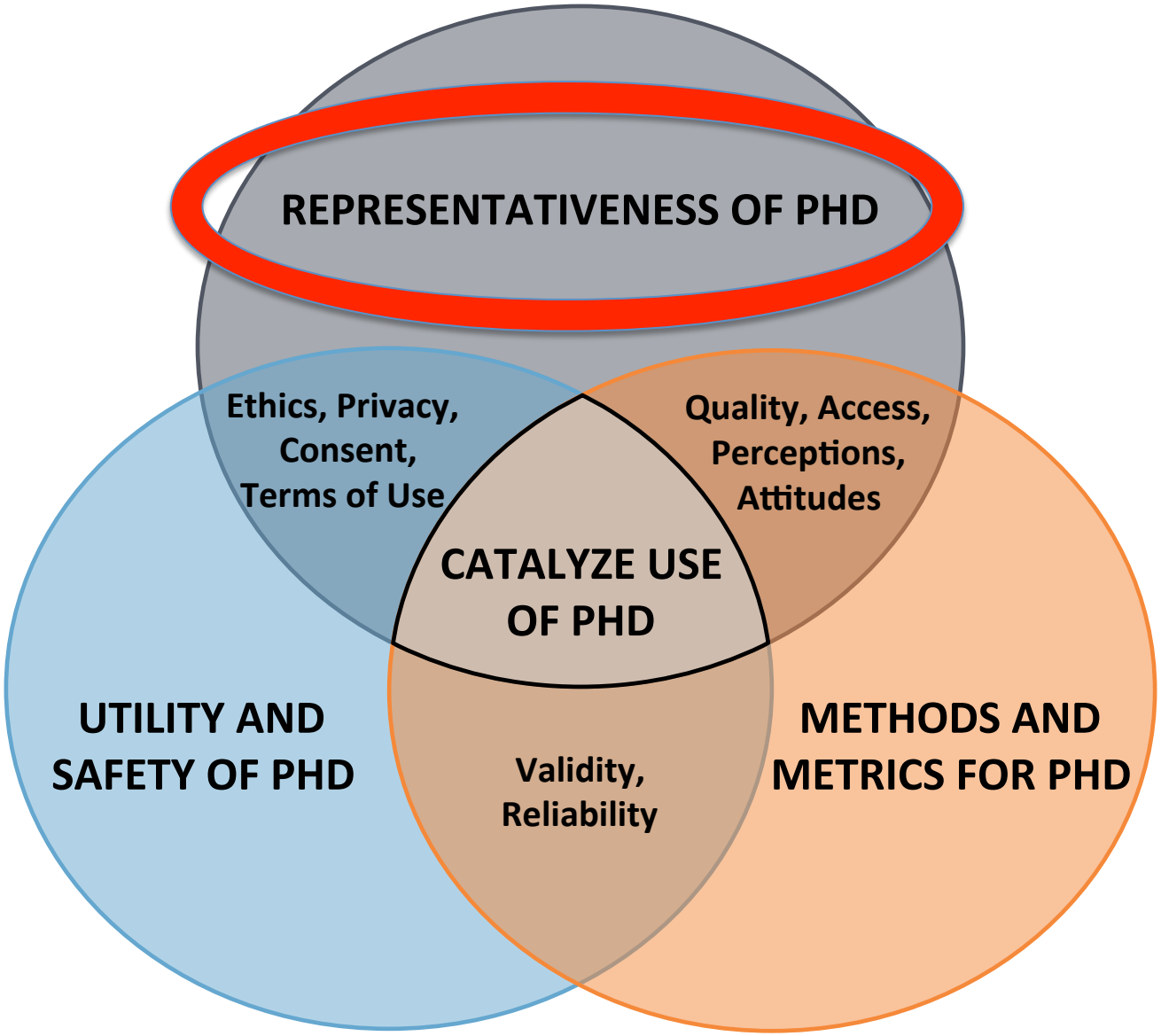
Judith Gregory, PhD, Adjunct Professor, UC Irvine
Scout Calvert, PhD, Project Scientist, UC Irvine
Ramesh Rao, PhD, Director, Calit2/UCSD

Report Available at:
hdexplore.calit2.net

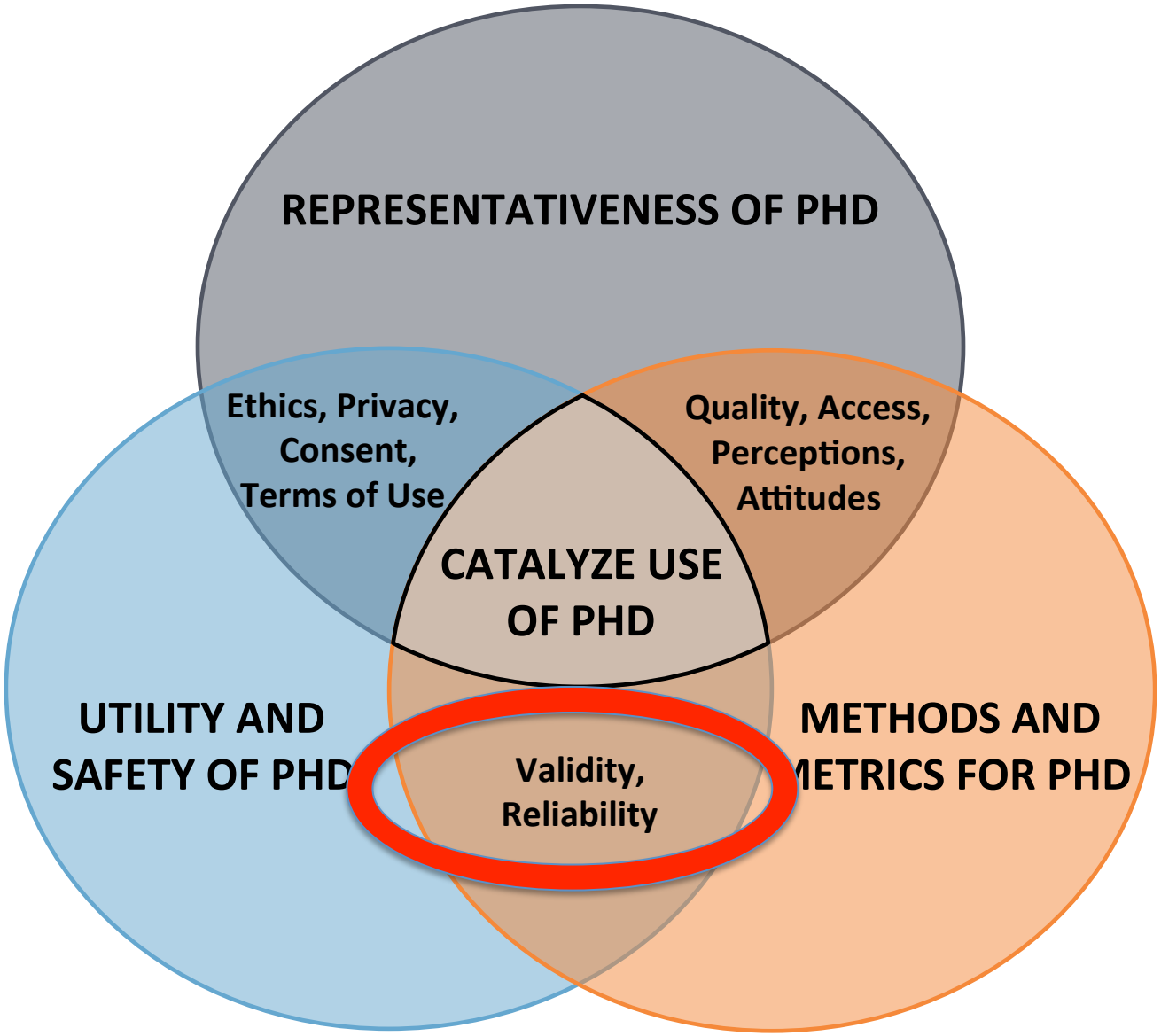
Robert Wood Johnson Foundation

Program Office Core Research Areas




Eric Fischer / Mapbox

Program Office Core Research Areas



Adolescent Brain Cognitive Development

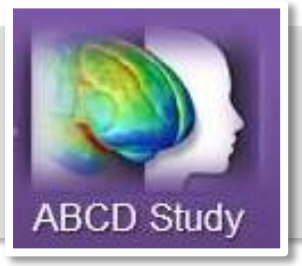
Teen Brains. Today's Science. Brighter Future.

10-year Longitudinal Cohort Study
of 11,000 children age 9/10 yrs. (on entry)
21 sites across the country

Adolescent Brain Cognitive Development (ABCD) Fitbit Validation Study

- N = 60 (30 males, 30 females)
- 9-10 years old
- Physically healthy
- Within San Diego County
- Fitbit Charge HR™
  - triaxial accelerometer (ACC)
  - optical heart rate monitor (HR)
  - alitimeter (ALT)
  - vibration motor
  - OLED display
  - Can collect data up to 5 days until recharge needed
- Purpose: formally evaluate validity of data recorded by Fitbit Charge HR in laboratory and field tests

ABCD Needs



Measures

- Physical activity
- Sleep
- Heart rate

Protocol

- Continuous (24 hrs/day)
- Duration (4 weeks)

Requirements

- Low cost
- Non-invasive (wrist worn)
- Passive data upload
- Easy data access
- Infrequent charging
- Form factor for children
- Low participant burden

CENTER FOR WIRELESS & POPULATION HEALTH SYSTEMS

60 participants **12** lab tests **5** field tests

UC San Diego

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

Measures of sleep and cardiac functioning during sleep using a multi-sensory commercially-available wristband in adolescents

Massimiliano de Zambotti [a], Fiona C. Baker [a,b], Adrian R. Willoughby [a], Job G. Godino [c,d], David Wing [c,d], Kevin Patrick [c,d], Ian M. Colrain [a,e,*]

Key findings:

Fitbit device is reliable in detecting standard polysomnographic (PSG) metrics.

Fitbit device performed well in detecting heart rate during sleep.

Similar to standard actigraphy, Fitbit device had lower ability in detecting wake.

FitbitChargeHR™ may be a valid alternative to PSG in healthy populations.

Physiology & Behavior 158 (2016) 143-149

#OpenAPS

is an open and transparent effort to make safe and effective basic Artificial Pancreas System (APS) technology widely available to reduce the burden of

Type 1 diabetes.

@DanaMLewis

#OpenAPS

"#WeAreNotWaiting to make basic closed loop APS technology more widely available to anyone with compatible medical devices who is willing **to build their own system.**"

Scott Leibrand and Dana Lewis, founders of OpenAPS and two of the developers in the community.

#OpenAPS:

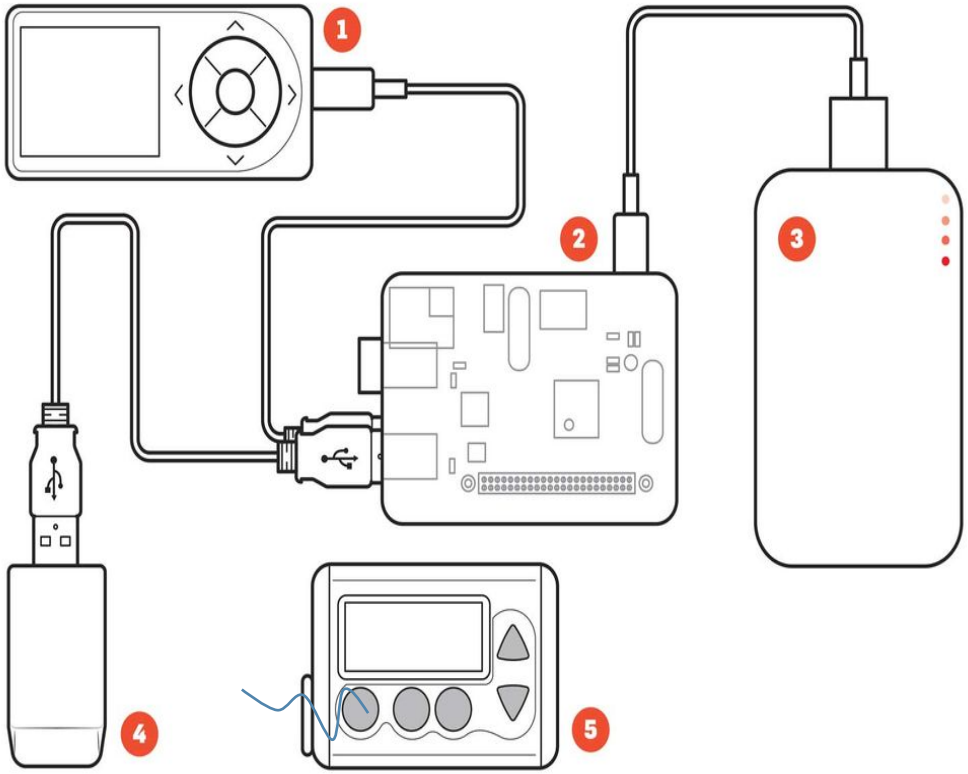
Taking the DIY, artificial pancreas from (n=1) to (n=1)*many by:

- **Focusing on safety**
- **Limiting dosing ability in hardware and software**
- **Using same dosing calculations a person would use**
- **Responding (or not) to unexpected data**
- **Tolerating communication failures**
- **Failing back safely to standard device operation**

@DanaMLewis

Reference design, code, documentation at OpenAPS.org

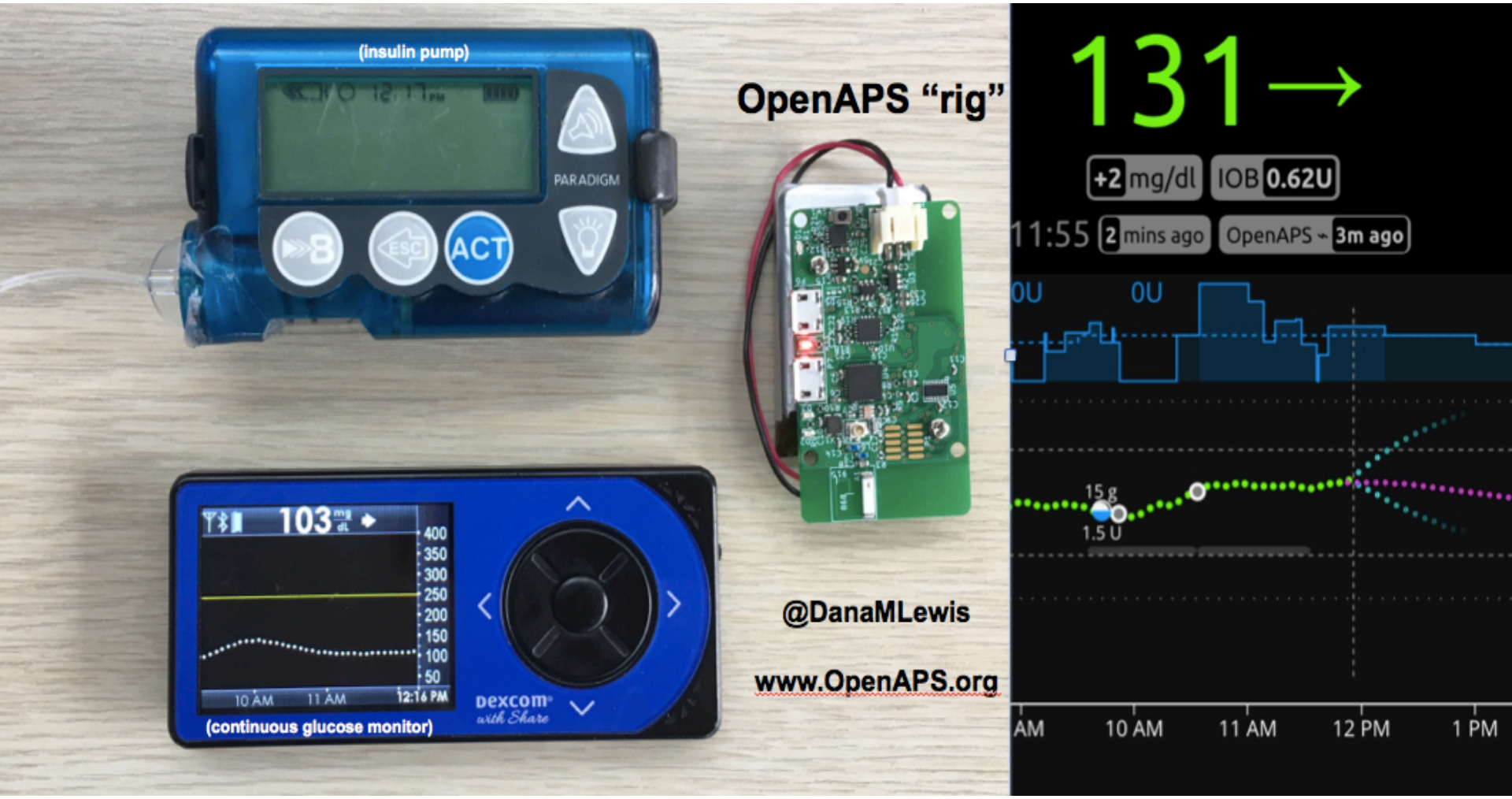
Components of an open source artificial pancreas



1. Continuous glucose monitor
2. Small computer ("controller")
3. Battery
4. Radio stick ("translator")
5. Insulin pump

(Illustration by Clint Ford for Popular Science)

@DanaMLewis


(insulin pump)
PARADIGM
ESC
ACT
OpenAPS “rig”
103
400
350
300
250
200
150
100
50
10 AM
11 AM
12:16 PM
dexcom
with Share
(continuous glucose monitor)
@DanaMLewis
www.OpenAPS.org
131 →
+2 mg/dl
IOB 0.62U
11:55
2 mins ago
OpenAPS
3m ago
0U
0U
15 g
1.5 U
AM
10 AM
11 AM
12 PM
1 PM


Thank You!
cwphs.ucsd.edu