Overview of Center for Wireless and Population Health Systems

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

Defense Health Board
February 10, 2016
Collaborating Investigators & Partners

**UCSD School of Medicine**
*Family & Preventive Medicine, Pediatrics, Medicine, Psychiatry & Emergency Medicine*

Kevin Patrick, MD, MS, Fred Raab, Linda Hill, MD, MPH, Jacqueline Kerr, 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

**UCSD Jacobs School of Engineering & The Qualcomm Institute**
Bill Griswold, PhD, Ingolf Krueger, PhD, Tajana Rosing, PhD, Sanjoy Dasgupta, PhD,
Yannis Papakonstantinou, PhD, Emilia Farcas, PhD, Nadir Weibel, PhD, Jessica Block, MS
Deborah Forster, PhD

**San Diego Supercomputer Center**
Chaitan Baru, PhD, Natasha Balac, PhD

**SDSU School of Public Health**
Elva Arredondo, PhD, Gregory Talavera, MD, MPH

**PhD students and Post-doctoral Fellows (current)**
Laura Pina, Ernesto Ramirez, Gina Merchant, Maggie Crawford, Marta Jankowska, PhD
Yannis Katsis, PhD, Max Menarino, PhD, Job Godino, PhD,

Funded by:
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
Areas of research

Health, Behavioral & Social Sciences

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

Wireless Technologies and Ubiquitous computing & data

- 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

Design

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

- Cog Sci
- Media/Comm
- Beh Sci
- Soc Sci
- Hum/Comp Interaction
Tech’s ‘Frightful 5’ Will Dominate Digital Life for Foreseeable Future

By just about every metric, Amazon, Apple, Facebook, Google and Microsoft are getting larger, more entrenched in their own sectors, more powerful in new sectors and better protected from competition.
CitiSense

Always-on Participatory Sensing for Air Quality

PI: UCSD, CSE
Five Co-PIs

Cyber-Physical Systems Program, NSF, 0932403
Impact of Environmental Exposure

- Asthma events are 50% higher near highways
- 30% of public schools are near highways
- 350,000 – 1,300,000 respiratory events in children annually
- Diesel exhaust → Carcinogen (WHO/IARC, 2012)
- Peak exposure → Cardiac events, increased hospitalizations
Current State of Air Quality Monitoring

- EPA requires local agencies to monitor air quality for their region.
- Required number of sensors, monitored pollutants are based on region size, population, regional issues.

10 monitoring sites for San Diego County
Participatory Sensing of the Environment
CitiSense: System Overview

Air Pollution Sensor

Map

Satellite

Hybrid

CO, NO, O₃, Humidity, Pressure, Temp

Upload Measurements
User Study of Individual Exposure

- Conducted a month-long user study (Spring 2012)
  - 16 users (two groups of eight users each)

- Recruited from the UCSD community
  - Students, faculty, and staff
  - Variety of commuting methods: car, bus, bicycle, motorized scooter, trolley, and train
  - Commute at least 20 minutes each direction

- Each user was asked to carry a provided smartphone and CitiSense sensor everyday
  - Compensated $75 for time, travel costs at conclusion
Individual Exposure vs. Regional Summary

March 15th, 2012
Data Enables Finer Grained Maps

Simple interpolation (using standard geostatistical kriging techniques)
CitiSense findings varied considerably from those provided by official EPA estimates (via EPA website)

Applying geostatistical kriging techniques allows CitiSense to infer a regional map with greater detail than official summaries

(Best Paper, Wireless Health, 2012)
Major influences on health
Health Data Exploration Project

Project Director: [Name]
Professor, Family and Preventive Medicine, UCSD
Director, Center for Wireless and Population Health Systems, Calitz

Project Co-Director: [Name]
Chief of Staff, Calitz

Investigators

[Names and affiliations]

PI: 1 individual
Co-Is: 2 individuals
2013-2017

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

Robert Wood Johnson Foundation
“Health happens where we live, learn, work and play.”

Robert Wood Johnson Foundation
Traditional Health Research

Randomized controlled trials

Biomarkers

EMRs

Surveillance

BRFSS

National Health Interview Survey
Since 1957
Planet of the phones

By 2020, 80% of adults will have a supercomputer in their pocket.
Wearable devices for tracking health-related states
Social Networks

Facebook:
156 Million Daily Users in US
1.55 Billion worldwide
(Q3, 2015)
The Internet of Things

Source: Cisco IBSG, April 2011
An increasingly diverse & expanding ecosystem of devices, apps, and services generating vast amounts of data...
Personal Data and Health

• New paths for reflection and self-improvement
  – Healthy behaviors and lifestyles

• New connections with clinical care
  – Mobile health applications
  – Monitoring & intervening on chronic disease

• New health knowledge from aggregate data
  – Public health surveillance
  – Health research
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

<table>
<thead>
<tr>
<th>Clinical Data</th>
<th>Personal Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Research Study</td>
<td>Context of Collection</td>
</tr>
<tr>
<td>Expensive</td>
<td>Cost per Observation</td>
</tr>
<tr>
<td>Validated</td>
<td>Measurement Trueness</td>
</tr>
<tr>
<td>Tuned to Research Qs</td>
<td>Data Specificity</td>
</tr>
<tr>
<td>Standardized</td>
<td>Comparability</td>
</tr>
<tr>
<td>Comprehensive</td>
<td>Completeness</td>
</tr>
<tr>
<td>Personal, Clear</td>
<td>Informed Consent</td>
</tr>
<tr>
<td>Definable</td>
<td>Ethical Issues</td>
</tr>
<tr>
<td>Highly Regulated</td>
<td>Confidentiality</td>
</tr>
<tr>
<td>Low Risk of Identification</td>
<td>Anonymity</td>
</tr>
<tr>
<td>Contrived</td>
<td>Ecological Validity</td>
</tr>
<tr>
<td>Periodic</td>
<td>Pace of Observation</td>
</tr>
<tr>
<td>Self-report</td>
<td>Behavior, Mood, Exposome</td>
</tr>
</tbody>
</table>

- **Clinical Data**
  - Used in research settings
  - Cost: Expensive
  - Validity: Validated
  - Specificity: Tuned to Research Qs
  - Standardization: Standardized
  - Completeness: Comprehensive
  - Consent: Personal, Clear
  - Definability: Definable
  - Regulation: Highly Regulated
  - Identification: Low Risk of Identification
  - Observation: Periodic
  - Source: Self-report

- **Personal Data**
  - Used in everyday life
  - Cost: Cheap
  - Validity: Unvalidated
  - Specificity: General Purpose
  - Standardization: Unstandardized
  - Completeness: Comprehensive
  - Consent: Mediated, Questionable
  - Definability: Definable
  - Regulation: Highly Regulated
  - Identification: Larger Risk of Identification
  - Observation: Continuous
  - Source: Sensed
Health Data Exploration Project

Project Director: [name blacked out]
Professor, Family and Preventive Medicine, UCSD
Director, Center for Wireless and Population Health Systems, Calit2

Project Co-Director: [name blacked out]
Chief of Staff, Calit2

Investigators
- [name blacked out], PhD, Project Scientist, UC Irvine
- [name blacked out], PhD, Adjunct Professor, UC Irvine
- [name blacked out], PhD, Project Scientist, UC Irvine
- [name blacked out], PhD, Director, Calit2/UCSD

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

Robert Wood Johnson Foundation
Building a Network

• Funded by Robert Wood Johnson Foundation in Fall, 2014

• Network of innovators in PHD to catalyze the use of personal data for the public good
  - Companies, researchers, and strategic partners

• Annual meetings, webinars, workshops, etc.

Info at: hdexplore.calit2.net
Health Data Exploration Network
Key Advisors & Steering Committee, 2015-2017
Technology Adoption

• Tends to be unevenly distributed in society
• Different communities will have different patterns of use
  – Access, usefulness, and usability
  – Perceptions of risks and benefits
  – Personal and collective motivations
• Influenced by a variety of social, economic, technological, and cultural factors
Validity & Reliability of Personal Health Data Derived from Consumer-level Wearable Devices: A Scoping Review

Project Leader: PhD
Research Associate, UC San Diego
Member HDE Core Team
Background
Challenge to Assess Validity

- Engineering specifications of sensors are difficult to find
- How sensors are utilized is often proprietary and secretive
- Extent to which design and materials influence measurement is unknown
- Process of bringing new models to market is outpacing independent evaluation
- No universal criteria for judging methodological rigor of studies
HDE Network
Agile Research Projects

• Small proof-of-concept, demonstration, or pilot projects: $25k-$75k, < 6 months
• Advance use of PHD for Research
• Leverage two or more network members
• Research teams will communicate regularly
• Results presented at Network Webinars
• Outcomes shared as openly as possible
Agile Research Project #1

When Am I At My Best? – Passive Sensing of Circadian Rhythms for Individualized Models of Cognitive Performance

PhD, U. of Washington
Tanzeem Choudhury, PhD, Cornell

Use smartphone data to capture interaction patterns, web use & sleeping behaviors
Conduct a 3-week feasibility study
Model trends in reports of cognitive performance & measured reaction times
Agile Research Project #2

From Self-monitoring to Self-experimentation: Behavior Change in Patients With Multiple Sclerosis

PhD, PatientsLikeMe
PhD, Arizona State University
PatientsLikeMe

Determine current status of using wearable devices for managing Multiple Sclerosis with emphasis on self-customization
Develop a “Wearables 101” course for MS patients
Pilot test the course among a group of patients & refine as needed
Major influences on health
Social Mobile Approach to Reduce Weight

NIH/NHLBI U01 HL096715; PI MD, MS and PhD
Design and implementation of a randomized controlled social and mobile weight loss trial for young adults (project SMART)

K. Patrick a,b,⁎, S.J. Marshall a,b, E.P. Davila a,b, J.K. Kolodziejczyk a,b,c, J.H. Fowler b,d, K.J. Calfas b, J.S. Huang a,e,f, C.L. Rock b, W.G. Griswold g, A. Gupta a, G. Merchant a,b,c, G.J. Norman a,b, F. Raab a,b, M.C. Donohue b, B.J. Fogg h, T.N. Robinson i

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ARTICLE INFO

Article history:
Received 24 April 2013

ABSTRACT

Purpose: To describe the theoretical rationale, intervention design, and clinical trial of a two-year intervention study (project SMART). The study hypothesizes that an internet-based, social support intervention is effective in promoting weight loss and weight maintenance in young adults aged 18 to 30 years.
“User-centered” Intervention

Website

Smartphone Apps

Email

Facebook

Text Messages

Health Coach + Virtual Facetime
Via phone & online chat

Other Tools
Bathroom Scale & Pedometer

Be sure to check your email for this week’s topic from ThreeTwoMe
“State of the Science” Theory

Core Behavior Strategies

- Intention Formation
- Goal Setting
- Goal Review
- Feedback on Performance
- Self-monitoring

Michie et al., 2009, 2011

Theoretical Principles

- Social Cognitive Theory
- Ecological Theory
- Social Network Theory
- Theories of Operant Learning
- Theories of Tailored Health Communications
- Self Regulation Theory
- Behavioral Choice Theory
## Suite of Apps

### Mobile Apps

<table>
<thead>
<tr>
<th>APP</th>
<th>Self-Monitoring</th>
<th>Intention Formation</th>
<th>Goal-Setting</th>
<th>Goal Review</th>
<th>Feedback</th>
<th>Knowledge</th>
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</thead>
<tbody>
<tr>
<td>Be Healthy</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>TrendSetter</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
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<tr>
<td>Goal Getter</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Facts &amp; Quizzes</td>
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<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

All apps accessible via
- ✓ Mobile
- ✓ Website
- ✓ Facebook

Copyright, Regents of the University of California, 2014
Facebook Page

- Christina – “The Health Coach”
- # of “Likes” overall
- # of “Likes” per post
- # of Impressions
- % feedback on the post
- Video on National Food Day
Design

**Inclusion Criteria**
- Owns a personal computer
- Owns a mobile phone and uses text messaging
- Facebook user or willing to start using Facebook

<table>
<thead>
<tr>
<th>Campus</th>
<th>n</th>
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<tbody>
<tr>
<td>SDSU</td>
<td>182</td>
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<tr>
<td>UCSD</td>
<td>164</td>
</tr>
<tr>
<td>CSUSM</td>
<td>58</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>404</strong></td>
</tr>
</tbody>
</table>

404 university students, 18-35 years old, 25 < BMI ≤ 34.9 kg/m²
Results: weight (kg)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>202</td>
<td>76.5</td>
<td>74.6, 78.5</td>
</tr>
<tr>
<td></td>
<td>196</td>
<td>76.8</td>
<td>74.8, 78.7</td>
</tr>
<tr>
<td></td>
<td>193</td>
<td>76.8</td>
<td>74.9, 78.8</td>
</tr>
<tr>
<td></td>
<td>183</td>
<td>76.9</td>
<td>74.9, 78.8</td>
</tr>
<tr>
<td></td>
<td>179</td>
<td>77.6</td>
<td>75.6, 79.6</td>
</tr>
<tr>
<td>Intervention</td>
<td>202</td>
<td>76.5</td>
<td>74.6, 78.5</td>
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<tr>
<td></td>
<td>185</td>
<td>75.4</td>
<td>73.5, 77.4</td>
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<tr>
<td></td>
<td>184</td>
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</tr>
<tr>
<td></td>
<td>162</td>
<td>76.8</td>
<td>74.8, 78.5</td>
</tr>
</tbody>
</table>
Additional Analyses

Subgroups
• Sex
• Age
• Ethnicity
• Engagement

Weight-related
• % change in weight
• % who lost at least 5%
• % who lost at least 3%
• % who did not gain weight
• % who did not gain more than 3%

Metabolic and Anthropometric
• Blood pressure
• Heart rate
• Waist Circumference
• Arm Circumference

Behavioral
• Physical activity
• Sedentary behavior
• Diet
• Sleep

Psychological
• Quality of life
• Depression
• Body image
• Self-esteem

Psychosocial
• Intentions
• Self-efficacy
• Social support
• etc...

Facebook and Social Networks
Facebook and Social Networks

- We have friendship data on 315 participants
- 114 (36%) participants are friends with at least one other participant
- There are 214 friendships between study participants (179 friendships when lost to follow-up are excluded)
- Degree summary statistics (# of other participants each participant is connected to):
  - Mean = 2.4
  - Median = 2
  - Range = 1 - 11
Facebook and Social Networks

Network Picture by Condition
Yellow = Control | Purple = Intervention
Does being in a weight-loss trial affect how much you talk about healthy living with your online social network?

- Create a Healthy-Active-Lifestyle (HAL) dictionary to flag posts as reflecting purposeful exercise and/or healthy eating
- Restricted to outgoing posts made by participant
- Quantify the # of HAL posts / total # of posts over study period
- Test whether treatment group has more HAL than control and whether engagement with study tools increases HAL
Does HAL Facebook activity predict weight loss? Does being connected to another participant who lost weight predict weight loss?

• Quantify the amount of social support for HAL on Facebook:
  1. Likes, comments to HAL posts made by participants
  2. HAL posts from friends

• Quantify engagement with the ThreeTwoMe Facebook page

• Quantify # of study friends who lost weight

• Test whether engagement with the ThreeTwoMe page and receiving online social support for HAL predicts weight loss after adjusting for other tool use
How does social network position, connectedness, and network structure affect weight loss efforts?

- Use individual (e.g., centrality) and network level (e.g., density) variables to describe the SMART network
- Test how individual and network variables are related to weight-related outcomes and behaviors
Connecting the dots....

Major influences on health
DELPHI

Data e-Platform to Leverage Multilevel Personal Health Information

PI
Co-PIs and Investigators

NSF 1237174, Information & Intelligent Systems
Multiple sources of health-relevant data

- Medical Records
- Personal Health Data (weigh-ins, run info, …)
- Environmental Data (pollution, noise, greenspace, …)
- Genomic Data
- Microbiome Data
- Public Health & Social Determinants Data
Providing health care & population health requires reasoning across these layers:

- **Behavioral & Social Data**
  - Physical activity
  - Sleep
  - Social Networks
  - Stress
  - Diet

- **Personal Medical Data**
  - Medical Records
  - Genomic
  - Pharmaceutical
  - BMI

- **Environmental Data**
  - Food & Grocery
  - Pollutants
  - Transportation
  - Crime & Incivilities

- **Diabetes Management**
- **Asthma Care**

- **Obesity tracking for public health**
Today: Most health data are either ignored or are functionally unavailable

Reasons:

- Data are collected and maintained by different entities
  - Making it hard to find and access them
- Data have different data types
  - Making it hard to combine them

Data Categories:

- Physical Activity Data
  - Runkeeper
  - Runtastic
  - Nike+
  - Jawbone
  - Fitbit

- Social Data
  - Facebook
  - Twitter

- Nutritional Data
  - Fooducate
  - MyFitnessPal

- Weight Data
  - Withings
  - Fitbit

- Medical Record Data
  - McKesson
  - Meditech
  - Cerner

- Genomic Data
  - 23andMe

- Environmental Data
  - Environmental Protection Agency
  - Air Pollution Control District

- Air Quality Data
DELPHI: The Goal

- Integrate heterogeneous data into a “single” uniform database
  - By taking into account the geospatial context
- Implement an analytics and visualization layer on top
- Open data and analytics to 3rd-party developers of apps & services

Enable personalized population health through the creation of a “Whole Health Information Platform” that takes into account everything from the genome to the exposome – essentially all health-relevant data

Partners

- Qualcomm
- San Diego Health Connect
- County of San Diego Health and Human Services Agency
- SANDAG
- Connect
DELPHI System Architecture

**Sources**

- Medical Records*
- Personal Sensor Data*
- Location Data*
- Smartphone
- Genomic Data
- Environmental Data
- Qualcomm Life
- BEACON Health Info Exchange
- 3rd party web-services

**DELPHI**

WHOLE HEALTH INFORMATION MODEL (WHIM)

**ANALYTICS LAYER:**
- Allows developers to run common analytics efficiently

**INTERFACE**

- WHAPI
- WHIM

**ANALYTICS**

**VISUALIZATION LAYER:**
- Allows developers to create common visualizations efficiently
- Developers to access all integrated health data and write apps that use them

**APPLICATIONS**

- Feedback, alert & advice
- Integrated view of patient + feedback
- Population statistics & analytics
- Medical Personnel Population Dashboard
- Other New Applications
- Goal: Create ecosystem for developers to create the next generation of health applications

**Patient/Parent App**

**Medical Personnel Individual’s Dashboard**

**Medical Personnel**
Use Case: Asthma

Environmental Data
- Air quality, County health

Personal (Sensor) Data
- Activities, Peak Flow, Self Report

Medical Records
- Hospitalization, Age, Flu shot

DELPHI

Patient/Parent App
- Probability of danger (machine learning algorithms) + contact to doctor

Medical Personnel
- Individual's Dashboard
- Integrated view of patient + feedback

Medical Personnel
- Population Dashboard
- Population statistics
Use Case: Asthma App
Use Case: Find correlations (and new causal relationships?) between and among different health-related variables using machine learning and other big data analytic strategies.
Use Case: Find correlations (and new causal relationships?) between and among different health-related variables using machine learning and other big data analytic strategies.
Research Challenges Addressed in the DELPHI Project

- Data Integration & Analytics in Novel Settings:
  - New data types
    - e.g. spatiotemporal data, genomic data
  - Dynamic environments
    - e.g. new sources & new applications join the system
  - Modeling this process in a defined geographical area
    - Use cases relevant to personal and population health
Our approach is to model access to as much health-related information as we can gather in San Diego County, Calif. Population 3.2 Million, 4000 Sq Miles
Thank You!
cwphs.ucsd.edu