Mobile Health & Precision Medicine: The Science, the Future, & Duke

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Precision Medicine

• Today: most healthcare is based on expected response of the average patient

• Tomorrow: healthcare will be based on individual genomic, environmental, and lifestyle differences that enable more precise ways to prevent and treat disease
Precision Medicine

• Not entirely new idea

Prescription Eyeglasses  Blood Transfusions
**IMPRECISION MEDICINE**

For every person they do help (blue), the ten highest-grossing drugs in the United States fail to improve the conditions of between 3 and 24 people (red).

1. **ABILIFY** (aripiprazole)  
   Schizophrenia

2. **NEXUM** (esomeprazole)  
   Heartburn

3. **HUMIRA** (adalimumab)  
   Arthritis

4. **CRESTOR** (rosuvastatin)  
   High cholesterol

5. **CYMBALTA** (duloxetine)  
   Depression

6. **ADVAIR DISKUS** (fluticasone propionate)  
   Asthma

7. **ENBREL** (etanercept)  
   Psoriasis

8. **REMICADE** (infliximab)  
   Crohn’s disease

9. **COPAXONE** (glatiramer acetate)  
   Multiple sclerosis

10. **NEULASTA** (pegfilgrastim)  
    Neutropenia

Based on published number needed to treat (NNT) figures. For a full list of references, see Supplementary information at go.nature.com/4e9788.
Precision Medicine

• Precision medicine will redefine our understanding of disease onset and progression, treatment response, and health outcomes through the more precise measurement of potential contributors

- for example, molecular measurements as captured through DNA sequencing technologies or environmental exposures or other information captured through increasingly ubiquitous mobile devices.
**Precision Health**

**GENOMICS**
Our genes can suggest what diseases we might be predisposed to, but it’s an incomplete picture of human health.

**PHENOTYPE**
A snapshot of the current state of health that can be used to prevent, diagnose and treat disease or improve health.

**LIFESTYLE/ENVIRONMENT**
External factors like diet, exercise, medications, microbiota and even where we live influence our metabolic state.
Precision Health

- Assess disease risks
- Customized disease monitoring
- Facilitate disease prevention
- Disease detection
Mobile Health

↑ MOBILE PHONES

↑ > 95% of US population (88% Rural)

↑ > 92% <$30,000/year

↑ > 77% of US population have a smart phone (67% rural)

↑ Socioeconomic backgrounds

↑ Most Geographic locations

↑ Direct reach

Pew 2018
Health Data Types
Shifting from the Clinic to the Cloud

Patient Reported Phone Sensors
Connected Devices
Environmental Data
Digital Phenotype

Jain, 2015 Nature Biotechnology
Smartphone

Phone sensors
Activity
Location
Sociality

Keyboard interaction
Reaction time
Attention
Memory

Voice and speech analysis
Prosody
Sentiment
Coherence

Digital phenotype
Behavior
Cognition
Mood

Measurement-based patient care
Diagnosis
Monitoring for remission and relapse
Risk prediction
CONSIDERATIONS

Benefits:
- Ability to integrate multiple data types to create a unique phenotypic signature
- Phenotypic signatures may be powerful indicators of health and disease
- Digital nature of phenotypic signatures facilitates integration with existing medical knowledge

Challenges:
- Requires a wealth of consumer-generated physiological and behavioral data to analyze
- Must be wary of spurious relationships

Individual composite score (proprietary combination of steps, sleep, and # of Facebook posts)

Composite scores of population

High risk individuals
### Types of Digital Biomarkers

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel</td>
<td>Novel insight</td>
</tr>
<tr>
<td>Known</td>
<td>Known insight</td>
</tr>
</tbody>
</table>

### Hypothetical Illustration: Blood Pressure

- **Measurement**:
  - Novel: Continuous blood pressure is used to predict the risk of a heart attack
  - Known: Discrete blood pressure data is used to predict depression

- **Insight**:
  - Known: Continuous blood pressure is used to predict depression
  - Novel: Discrete blood pressure data is used to predict the risk of a heart attack
Chronic Illness

#1 HEALTH RISKS

- Heart Disease
- Asthma
- Diabetes
- Cancer
- Arthritis
- Depression
Mobile Health at a Glance

- Patient is prompted to capture data (habits/activities/measurements/symptoms)
- Data streams collected and transported by mobile phone
- Geocoded and time-stamped self-reports, measurements, and activity traces stored securely to ensure privacy
- Processing to distill measures, trends and patterns
- Analysis/visualization/feedback

Feedback returned to patient

Feedback sent to provider
Fitbit - Bluetooth
Data: Pedometer, Sleep

Fitbit scale - FTPS
Data: Weight

iHealth scale - WiFi
Data: Weight

iHealth BP monitor - Bluetooth
Data: Blood Pressure

iHealth Glucometer - Bluetooth
Data: Glucose

Participant

Fitbit App - FTPS
Data: Pedometer, Sleep, Dietary

Fitbit Online Dashboard

iHealth - FTPS
Data: Pedometer, Sleep, Dietary, Blood Pressure

iHealth Online

Mobile Health Platform
Data:
- Secure server
- Aggregation
- Tracking
- Analysis
- Algorithms
- Scheduled message delivery

iHealth App - Bluetooth
Data: Blood Pressure

iHealth Glucometer - Bluetooth
Data: Glucose

SMS/Text
Data: Phone number, health messages

E-mail
Data: Phone number, health messages

Data:
- FTPS
- HTTPS
- Data: Phone number, health messages
- HTTPS
Growth Chart
Boston Children’s Hospital

Estimate a patient’s 10-year risk of heart attack or stroke with an intuitive interactive display.
Cardiac Risk
Boston Children’s Hospital

Estimate a patient’s 10-year risk of heart attack or stroke with an intuitive interactive display.
Log2Lose
Incentivizing behavior change skills
to promote weight loss

Corrine Voils, PhD & Ryan J Shaw, PhD, RN
NHLBI R34 HL125669-01
Episodic to Real-Time Care in Diabetes Self-Management

6 MONTHS

Data Visualization
New Kinds of Digital Phenotypes

![Proportion Missing Weight ± 1 SE, by Age (44 or Younger, 45+)](image1)

![Proportion Missing Weight ± 1 SE, by Diabetes Control Group](image2)
How it Works

While your child watches a video on your iPhone, we will record your child’s face to measure emotion.

You can choose to share the video or only the facial expressions.
Empatica E4 Specifications

Battery life
Streaming Mode: 20+ hrs
Memory mode: 36+ hrs

Data Management
Flash memory
Bluetooth LE (Smart)

Form Factor
Small and comfortable
Case: 44 mm x 40 mm, height 16 mm
Weight: 25 gr

Event Mark Button

Certification
CE certification
FCC certification

Sensors
Photoplethysmography (PPG)
Continuous Heart Rate (HRV, Stress, Relaxation)

3-axis Accelerometer
Movement, Activity

Temperature + Heat flux
Activity, Context

Electrodermal Activity (EDA)
Skin conductance (Arousal, Excitement)

Measure both branches of the autonomic nervous system.

Electrodermal Activity

Continuous Heart Rate
• Privacy
• Security
• Regulations
New Models of Care Delivery
Payment Models

There are 3 major complementary payment models being deployed in US

**Population-based payment**
- Capitation

**Episode-based payment**
- Retrospective Episode Based Payment (REBP)
- Bundled payment

**Pay for performance**
- Bonus payments tied to quality
- Bonus payment tied to value

**Most applicable**
- Primary prevention for healthy
  (e.g., managing obesity, CHF)

- Acute procedures
  (e.g., CABG, hips, perinatal)
- Most inpatient stays including post-acute care, readmissions
- Acute outpatient care (e.g., broken arm, URI, some cancers, some behavior health)
- Discrete services provided by entity with limited influence on upstream or downstream costs
  (e.g., MRI, prescription, medical device, Health Risk Assessment)
Focus Areas

Providing services to accelerate app development

Leadership in Digital Health

Education and Outreach

MAG Focus Areas
Education & Community

• Monthly workshops and seminars

• 228 attendees since January 2018
  • New FDA guidelines
  • Creating Engaging Mobile Apps
  • Intro to Design Thinking
  • Medable 101 Workshops
  • Digital Health Devices
  • Coffee & Case Studies
  • Networking events
Process Coordination

• Duke’s first ever Software Vendor Pre-certification program: 6 software development companies attended

• Regular meetings with central offices to improve efficiencies and encourage innovation
  • Ethics review
  • Data security
  • Technical
  • Contracts/legal
  • FDA regs
  • Commercialization

• Work with DHTS Digital Strategy Office to integrate wearable technologies, apps, and other technologies in clinical practice
Development Partners

WILLOWTREE®

LITTLE GREEN SOFTWARE

MEDABLE

SMASHING BOXES

NEW MEDIA CAMPAIGNS

CrossComm creativity + technology
Medable

• Contract - low cost DIY app builder

• RFA released, three apps funded and under development:
  1. Eliminating Chronic Opioid Use: Predicting patients at high risk for chronic opioid use and creating algorithms to responsibly tailor opioid prescribing and weaning after surgery (Whitsell et al, Anesthesiology)
  2. Track Light: Weight loss using a diet and physical activity tracking app (Steinberg et al, DGHI)
  3. Identifying treatment barriers affecting inflammatory breast cancer patients to improve care (Devi et al, Surgery and Pathology)
MS Mosiac
Medical Guidelines

• Duke Medical Guidelines App
  • Mobile responsive web-app for easy bedside access of Medical Guidelines, Policies, and Procedures for patient care on a department specific basis.

• 3 departments piloting: Pediatric Cardiac ICU, Trauma, Neonatology

• Moving towards making available for all departments
REDCap – Texting

<table>
<thead>
<tr>
<th>Twilio SMS and Voice Call services</th>
<th>Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twilio account credentials (obtained from Twilio website)</td>
<td></td>
</tr>
<tr>
<td>Twilio Account SID</td>
<td></td>
</tr>
<tr>
<td>Twilio Auth Token</td>
<td>********</td>
</tr>
<tr>
<td>Twilio phone number</td>
<td></td>
</tr>
</tbody>
</table>

**Has Twilio’s ‘Request Inspector’ been disabled for this account?**

A Twilio feature named Request Inspector causes all activity to be logged in detail and stored on Twilio’s servers. For the highest level of privacy, it MUST BE DISABLED in your Twilio account in order to be able to utilize the Twilio services in REDCap. You will find this setting on the Configure page under 'Voice, SMS & MMS'.

⚠️ Has not been checked! You must check it now before Twilio services can be enabled.

**Check it now? [ ]**

Note: Performing this check will cost a small amount of money, in which your Twilio account to be charged with a one-minute phone call.
REDCap – MyCap

• Campus Precision Health Project

• MyCap – REDCap iOS & Android interface

• Partnership with Digital Strategy Office: Prescribable and PRO apps through Epic
Digital Prescribing

• "prescribe" medical products and services to patients before discharge

• Fulfilled by Amazon or another e-commerce company, and Prime members could get discounts

• Complex medical conditions, new mothers, and people recovering from common procedures and surgeries
References


Questions