Patient self-care innovation happens outside traditional clinical workflows

mhealth can transform previously unmeasured behaviors and practices into personalized, evidence-based, and evidence-producing care
mHealth

Use mobile devices to enhance health and wellness by extending health interventions and research beyond the reach of traditional clinical care.
Outline

• what is mHealth
• an example system and supported pilots
• some open research challenges

Message

• mHealth is broadly applicable to patient self-care and clinical care
• mHealth data capture-analysis-presentation-action needs good statistics, software, HCI, open systems architecture, and privacy design practices
• mHealth might even act as a forcing function for new techniques
• mhealth presents an opportunity/need to increase everyday stat and computational thinking literacy
Whose mHealth?

· A woman who is pre-diabetic tracks how eating/exercise habits affect weight and fatigue; also explores effective, comfortable blood pressure Rx dosage.

· A young man who is struggling to find a treatment plan for depression believes medication dose is ineffective; doctor blames poor sleep habits/non-adherence. Patient self-monitoring includes medication reminder/verifications, sleep survey, activity traces, to guide adjustments in care plan, discussion of root causes.

· A middle-aged woman who does not respond well to medication for psoriasis monitors diet, stress, environmental factors; initiates data campaign via social networking site for psoriasis sufferers. Each volunteer runs mHealth app for 2-months to create large data set to mine for patterns that precede flare-ups.

· A group of high schoolers with asthma map their inhaler use and make a case for shifting Track practice to an alternate location farther from the freeway.
Integrated personal data streams will create *Living Records*

Automatically prompted, geocoded, uploaded, analyzed:

- physiological (weight, BP, glucose…)
- patient reporting (medication, symptoms, stress factors)
- activity (location traces, exercise, sleep)
- contextual, environmental, social factors

Technical challenge to extract relevant features, trends, patterns, anomalies

Living records serve 3 essential feedback loops in health: participant self-care, participant-clinical care, research evidence
Our software system: Ohmage
(source code available for download on github)

Tangmunarunkit, et al
Initial data capture functions of our mHealth system resulted from participatory design process with health innovators and target users.

Many common mechanisms apply across mHealth applications.

Ramanathan, Selsky, et al
Notable feature requests

- **Images**: Moms LOVED this feature for food, SA women did not.

- **Triggers**: Control of timing important to all--need trigger authoring and personalization

- **Buttons**: Most moms willing to answer at least briefly ‘in the moment’, while SA women almost all wanted to answer only at the end of the day.

- **Feedback**: Very few interested in seeing simple quantifications of their responses. Helpful tips and motivational messaging most popular. SA explicitly preferred *against themselves* vs competitive feedback with group.

- **Server vs Phone**: Very few willing/interested to access server. Most wanted interaction solely on phone.

Based on >100 (somewhat) diverse participants: young moms, young men living with HIV, immigrant women, breast cancer survivors, and recruited UCLA student testers
Initial data analysis functions resulted from *collaborative design* process with health innovators: much more work yet to do.

Correlations in time and space

Actigraphy over space

Actigraphy over time

Ramanathan, Selsky, et al
Goal: Support systematic shared learning through methods and tools used across many conditions, populations, investigations.
Clinical pilots drive the process

- Patricia Ganz, MD, UCLA Oncology
  - Mood and energy among breast cancer survivors (Completed Aug, 2011)

- Mary Jane Rotheram-Borrus, PhD & Dallas Swendeman, PhD Psychiatry UCLA
  - Cardiovascular disease risk factors in young moms (To be completed February 2012)
  - Risk behaviors for people living with HIV (To be completed December 2011)

- Namratha Kandula MD, Medicine Northwestern
  - Diet, mood, exercise in South Asian immigrant populations (To be completed October 2011)

- Fred Sabb PhD, Psychiatry UCLA
  - ADHD in Young Adults, validity and efficacy of self monitoring through self-report, go-nogo games, and activity traces (Pre-pilot completed August 2011; Phase I pilot to be completed December 2011)

- Joe Rusek, Julia Hoffman et al, NCPTSD VA
  - With openmhealth.org, Leveraging data from a modified version of the VA PTSD Coach application (see appstore) to create data for clinicians to use in treatment (Phase I pilot to be completed May 2012)
Ohmage addresses initial needs raised by health collaborations

- **Usability for end-user**
  - Experience sampling, light-weight data capture, automated actigraphy and location
  - Smart reminders, including location and activity
  - Battery-preserving sensor services
  - End-user dashboards: Visualization, analysis dashboards

- **Functionality for health innovators:**
  - Survey authoring
  - Researcher dashboards: System, study monitoring

- **Developer community engagement:**
  - Open-source releases
  - Admin dashboards: Rich user analytics

much more to do....
Smart Reminders

Location-based

Time range
Trigger only during the following interval
Start Time
5:35 pm
End Time
5:35 pm
Trigger always
Trigger at End Time even if not reached
Minimum re-entry
120 minutes

Time-based

Trigger Time
11:27 am
Repeat
Everyday
Time range
Enforce a range for the trigger time
Start Time
11:27 am
End Time
11:27 am
Randomize
Use random trigger times
Tangmunarunkit, et al
System instrumentation, analytics

- Remaining battery on phone
- User interaction with phone
- Memory usage on phone

Filter by location, time, user
Android Cross-platform app: in development with developers of mobile web framework (MWF)

Self-reported surveys

Data presentation
- Form
- Plots
- Maps

Feedback

Access to native device
- Camera
- GPS
- Accelerometer

Reminders

Access to native applications
- Mobility classifier
- Background process

Automated capture

HTML5, MWF

PhoneGap (or tools that support plugins to native devices and apps)

Tangmunarunkit, et al
Key research challenges

- **Health sciences community:**
  - Establish validity and reliability of mHealth instruments
  - Derive efficacy evidence base from rich usage, system analytics
  - Behavior change: defining, implementing, and adapting interventions that support sustained and beneficial change across populations

- **Technical community:**
  - Resource management, efficiency (enable full-day phone operation with background activity and data capture)
  - User modeling for activity classification, context, triggers
  - User engagement/experience: motivate sustainable user participation with game mechanics, adaptive interfaces
  - Infovis: analysis, presentation, visualization, for self, clinician, researcher
  - Selective sharing, usable privacy tools
  - Open systems
Adaptive battery management for background applications

- **Usage** and **context** matter for battery management, e.g., 15% left battery at 10pm is not the same as 15% at 10am.

- Battery and resource monitor continuously guides applications to consume enough power to meet the deadline; trading off fidelity/resolution

Falaki, et al
Objectives

- energy-efficiently sense semantic locations on battery-limited mobile devices
- automatically learn and recognize semantic places and paths closer to user’s interpretation of location
- motivate user feedback to bridge between machine-learned and human-defined places

Selectively leverage GPS/Wi-Fi/Accelerometer when each is informative/efficient

- people spend approximately 89% indoors, 5% in a vehicle, and 6% at outdoors on average
InfoVis
extract and present relevant trends, patterns, anomalies, correlations across diverse data streams and to diverse audiences

Needs: pre-processing, feature extraction, integration with machine learning libraries and statistical analysis tools, incorporation of external datasets, geospatial analyses, informative and configurable presentation

In progress: scaffolding for creating processing pipelines with r (and other) modules: Jeroen Ooms, Mark Hansen, Josh Selsky
“feedback” should look more like this than a data summary and be tailored to individual participants-- *Ubifit (UW, Intel)*

**Ubifit garden**

using on-body sensing, activity inference, and a personal, mobile display to encourage regular and varied physical activity

participants who...

had the garden

---

**did NOT have the garden**

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1 intel research seattle

2 dub, u of washington

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*consolvo, mcdonald, landay, chi 09* *consolvo et al, ubicomp 08* *consolvo et al, chi 08* *choudhury et al, ieee pervasive mag '08* *froehlich et al, mobisys '07* *consolvo, paulos, smith, mobile persuasion '07*
User engagement:
informational incentives, feedback, game mechanics

Informational incentives, e.g., analytics about actions, encourage participation initially--See Consolvo, Choudhury, Mynatt

Micro-payments/rewards promoted even (sustained) participation in community data gathering--might also apply for participatory mHealth Reddy, et al 2009:
- Micro-payments based on competition worked best for short bursty data collections
- Very low baseline micro-payments discouraged individuals

Future directions: game mechanics, social media tie-ins, goal setting and monitoring tools, adaptive over time for sustainability, configurable

Mobile Ambient Wellbeing Display (T. Choudhury, Cornell)
mHealth is about powerful traces of our daily lives ...but are these raw traces sometimes too telling?

Quantify habits, routines, associations
Easy to share and mine; but difficult to anonymize
Data handling by mobile carriers, credit card companies, is regulated
But...individual is free to capture and share her own data for free apps and services: “Everything is free to you, except for the data we collect about you”

Calls for new privacy practices...
Personal Data Vault (PDV): allow participants to retain control over their raw data by decoupling capture and sharing

**Mobile App**
- Data Capture / Upload (Prompted, Automated)
- Reminders
- Feedback, Incentives

**Personal Data Vault**
- User Identity and Authentication
- Long-term Data Management

**Third Party Services**
- Analytics for Personal Data Streams
- Interface to Clinical Care Plan, Personnel
- Integration with EHR/PHRs
- Cross Patient Aggregation

Well defined interfaces allow mobile functions to be mixed, matched, and shared

Patient defined selective sharing with Open mHealth Server function

Well defined interfaces allow analytics functions to be mixed, matched, shared, compared

vault + filters = granular, assisted control over what/when you send to whom, what data says about you, whether you reveal who you are or share anonymously, ...

M. Mun, et al, CONEXT 2010
Open architecture and community

*promote rate, range, rigor, and robustness of innovation and productization, particularly in the above-the-waist sense-making tools that consume mHealth data and make them useful to end-users*

http://openmhealth.org
Open platforms promote innovation and transparency

Bootstrap rapid cycle of learning, sharing, deployment
- ~80% (guesstimate) system components reusable
- Largest missing pieces: authoring, analysis-visualization, feedback

Facilitate research in methodology, treatment
- Systems gather usage data automatically for evaluation, iterative improvement
- Encourage modularity and sharing in methodologies, practice

Development in the context of real applications and use
- Collaborative/participatory design process with continual feedback from users
- Diverse targeted pilots inform generalization, adaptation, expansion.

Explore balancing of privacy protection and data sharing
- Variety of privacy/sharing policies
- Transparency of research and data processes for participants
mHealth is

• self measurement to support patient self-care, clinical treatment and research; with the potential to fuel transformational learning, particularly for chronic disease

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Acknowledgments: Collaborators and Sponsors

Collaborators

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