Smartphones are proximate, pervasive, programmable, personal; offer data/interaction in real time, real place, real context

in collaboration with faculty, students, staff at CENS, UCLA, UCSF...

Smartphones are proximate, pervasive, programmable, personal; offer data/interaction in real time, real place, real context
mHealth

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

our actions

our self report

personal data repository

experience sampling streams

context and activity traces

aggregate measures, trends, patterns

event detection

processing

visualization

Photo: Marshall Astor, WWW
Why *participatory* mHealth?

**motivation**
3 behaviors (diet, exercise, smoking) cause 1/3rd of US deaths
50% Americans have 1 or more chronic diseases
age of onset getting younger
chronic disease prevention/management/research happens in the context of daily life, outside of clinical setting

**approach**
support individuals, communities, clinicians to continuously improve patient-centered, personalized, health and healthcare.
mobile devices offer proximity, pervasiveness, programmability, personalization, affordability.
AndWellness
built to explore participatory mHealth

Data collection → Internet → Dashboard access

Data analysis, privacy preserving storage

Ramanathan, Selsky, et al
Phonetop

Bu:ons

Internet

GPS

ACCELEROMETER

Loca0on	
  and

0me	
  triggered

surveys

Automated
capture

Phonetop
Buttons

Ramanathan, Selsky, et al

Ramanathan, Selsky, et al
Participatory design: functionality shaped by focus groups, interviews

>100 (somewhat) diverse participants: young moms, young men living with HIV, immigrant women, breast cancer survivors, and recruited UCLA student testers

Ramanathan et al

Thursday, July 14, 2011
## Focus groups summary (n=72)

<table>
<thead>
<tr>
<th>Population</th>
<th>Primary application features discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Young Moms</strong> n=23</td>
<td><em>Engaging participation without increasing user burden</em></td>
</tr>
<tr>
<td></td>
<td>• Customization of reminder times/locations for convenience</td>
</tr>
<tr>
<td></td>
<td>• Image capture of food to increase accountability</td>
</tr>
<tr>
<td></td>
<td>• Set, manage, and monitor progress towards a goal</td>
</tr>
<tr>
<td></td>
<td>• Light-weight data capture</td>
</tr>
<tr>
<td></td>
<td>• Primary interaction to take place on the phone</td>
</tr>
<tr>
<td><strong>Immigrant Women</strong> n=20</td>
<td><em>Mechanisms to help people achieve a goal</em></td>
</tr>
<tr>
<td></td>
<td>• Set, manage, and monitor progress towards a goal</td>
</tr>
<tr>
<td></td>
<td>• Helpful tips and problem solving (suggested by phone)</td>
</tr>
<tr>
<td><strong>People Living with HIV</strong></td>
<td><em>1) Privacy and security of data</em></td>
</tr>
<tr>
<td>n=29</td>
<td>• Password protection on phone a must</td>
</tr>
<tr>
<td></td>
<td>• Nondescript text to hide the intent of sensitive questions</td>
</tr>
<tr>
<td></td>
<td>• Location tracking is controversial, granular control a must</td>
</tr>
<tr>
<td></td>
<td>• Data anonymization for sharing with counselor, coach, medical provider</td>
</tr>
<tr>
<td></td>
<td><em>2) Customization of Reminders</em></td>
</tr>
<tr>
<td></td>
<td>• Medication adherence reminders, especially using location</td>
</tr>
<tr>
<td></td>
<td>• Safe sex reminders</td>
</tr>
</tbody>
</table>

Ramanathan, Swendeman, Dawson, Estrin, Rotheram-Borus
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.
Correlations in time and space

Internet

End-User Dashboards

Work in progress for future release: time delayed correlations and correlations across behaviors

Ramanathan, Selsky, et al
Iyer, Ramanathan, et al

* To Be Released August, 2011

**Output Statistics**

<table>
<thead>
<tr>
<th>Activity Level</th>
<th>Avg. (mins)</th>
<th>Min. (mins)</th>
<th>Max. (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>10.00</td>
<td>0.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>10.00</td>
<td>0.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Vigorous</td>
<td>30.25</td>
<td>2.00</td>
<td>45.00</td>
</tr>
<tr>
<td>Total Time</td>
<td>50.25</td>
<td>17.00</td>
<td>65.00</td>
</tr>
</tbody>
</table>

**Graph Summaries**

- Overeating: How filling are your meals.
- Sleep Quality: How adequately have you been sleeping?
- Sleep Progression: How much time have you been sleeping?
- Negative Moods: What times of day were you in a bad mood?

**Legend**

- Too little/not enough: 15.6%
- Just right: 57.8%
- Too much: 24.4%

**Configure**

- Define Summaries
- Exercise Statistics (0)
- Meal Origins (0)
- Workout Intensity (0)
- Stressful Times (0)
- Meal Group Habits (0)

**Table Summaries**

<table>
<thead>
<tr>
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</table>
Of course...“feedback” should look more like this 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

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

\(^1\) intel research seattle

\(^2\) dub, u of washington

Thursday, July 14, 2011
Survey Creation

Survey Participation

Survey response rate

Number of days

Population Statistics

* in progress for release, Dec, 2011

Ramanathan, Selsky, et al
Admin Dashboards

Remaining battery on phone

User interaction with phone

Memory usage on phone

Filter by location, time, user

Wu, Falaki, Estrin, Ramanathan
AndWellness system implementation

Server-side defined by HTTP APIs: GET and POST using JSON, standard HTTP data packaging

What lies behind exposed API calls could be written in any programming language.

Ramanathan, Selsky, et al
Status of AndWellness features to date
(with guesstimate on how far along we are)

- Experience sampling, light-weight data capture (50%)
- Visualization/data presentation for end-user and researcher (15%)
- Smart triggers based on user configurable location, time, activity (25%)
- Background services for actigraphy, location tracing, system analytics (50%)
- Battery-preserving background services (50%)
- Open mHealth community building (15%)
- Participatory privacy policies and mechanisms (15%)

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

**Energy Source**

**Interaction Metrics**

**Phone Resources**

**SystemSens**

**Andwellness**

Energy Budget

GPS

ACCELEROMETER

Thursday, July 14, 2011
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

Signal patterns of surrounding RF beacons are noisy but useful for detecting semantic places

Many power saving opportunities exists when the device is immobile

GPS position fixes are inaccurate most of the time but informative when traveling paths connecting places
User modeling (sic) Using community similarity networks to handle population diversity (T. Choudhury, Cornell)
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)
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

![Mobile App Image]

**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

![Personal Data Vault Image]

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

![Third Party Services Image]

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

**Personal Data Vault (PDV):**
allow participants to retain control over their raw data by decoupling capture and sharing

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

M. Mun, et al, CONEXT 2010

*Thursday, July 14, 2011*
But...can we make selective sharing usable?

1. Upload raw data
2. Configure privacy policies/ACLs
3. Request data
4. Filter data to send
5. Send the filtered data
6. Check easy-to-read reports about continuous data sharing
7. Reconfigure ACLs

Step 6 and 7 can be repeated

M. Mun, et al, CONEXT 2010
Importance of an open platform: avoid silos, 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
- STransparency of research and data processes for participants
“Approximately 25 years ago, government and industry invested in expanded access at a crucial time in the Internet’s development. The resulting networks and ubiquity of access provided fertile ground for technologies, ideas, institutions, markets, and cultures to innovate. The payoff from this investment created a commercially viable and largely self-governing ecosystem for innovation.

The same can be done for global health. Government, commercial, and nongovernmental entities involved in health IT and innovation should cooperate to define and instantiate architecture, governance, and business models and to steer initial mHealth investments into open architecture.”


**Summer reading recommendations:**

The filter bubble, Eli Pariser

Everything is Obvious*, *once you know the answer, Duncan Watts

Open mHealth initiative: [http://openmhealth.org](http://openmhealth.org)
Acknowledgments: Collaborators and Sponsors

Collaborators

**Technology faculty, PIs:**
Deborah Estrin, Mark Hansen, **Nithya Ramanathan**

**Application/domain expert faculty/PIs (Health science):**
Robert Bilder, Jacqueline Casillas, Scott Comulada, Patricia Ganz, Mary Jane Rotheram-Borus, **Ida Sim** (UCSF), Fred Sabb, Dallas Swendeman, Michael Swiernik

**Students, staff:**
Staff: Betta Dawson, John Jenkins, Mo Monibi, **Joshua Selsky**
Graduate students: Faisal Alquaddoomi, Hossein Falaki, Brent Flagstaff, John Hicks, Jinha Khang, Donnie Kim, Min Mun, Katie Shilton

Sponsors and Partners/Collaborators

**UCLA centers:** CENS, Global center for families and children, Health Sciences, JCCC

**Federal funding:** NSF STC and NETS-FIND Program, NIH

**Corporate funding:** Google, Intel, MSR, Nokia, T-Mobile

**Foundations/NGOs:** The California Endowment, RWJF, CHCF, CRA