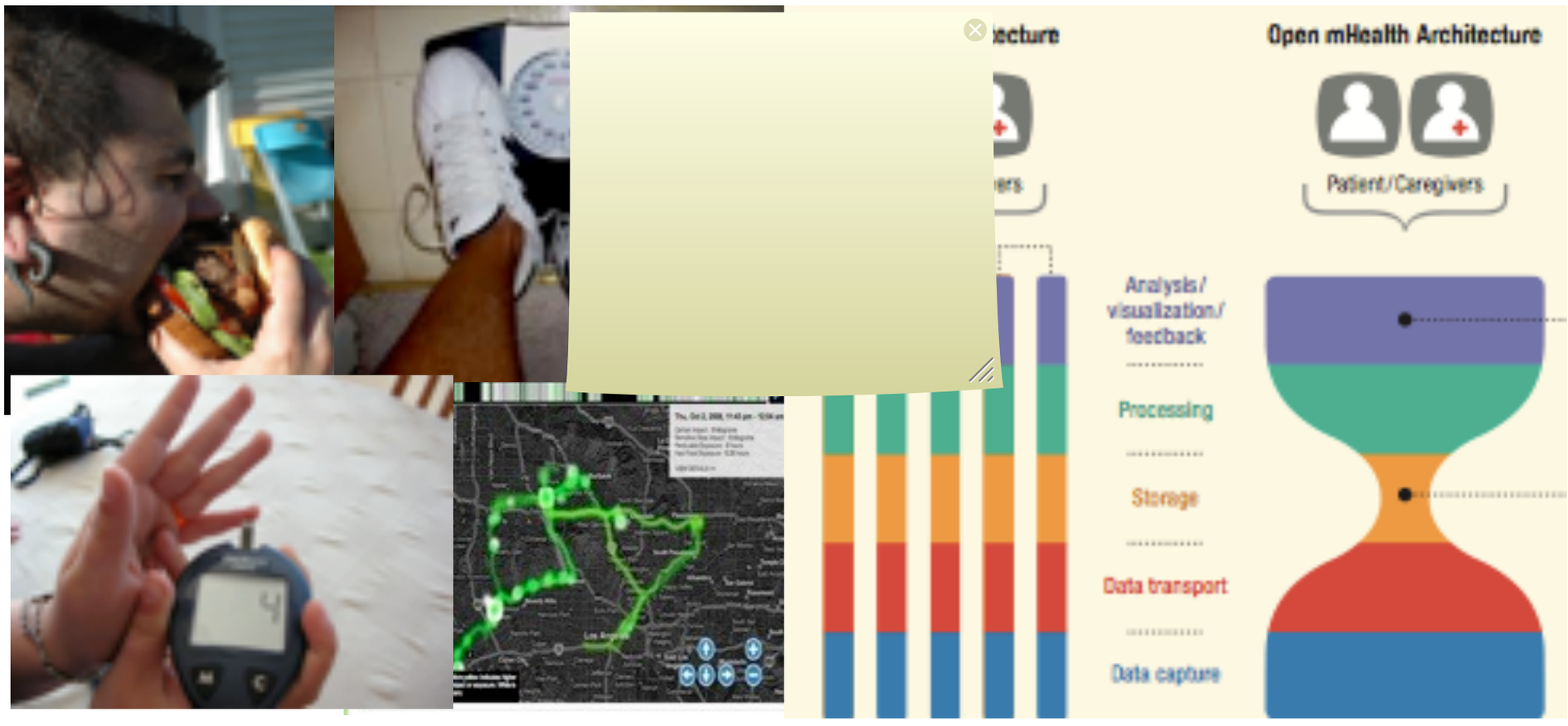
Participatory mHealth

Deborah Estrin
UCLA Center for Embedded Networked Sensing (CENS)
and OpenmHealth.org
destrin@cs.ucla.edu

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



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.

our actions

Photo: Marshall Astor, WWW

our self report

personal data repository

experience sampling streams

context and activity traces

visualization

aggregate measures, trends, patterns

event detection

processing

Why m(obile)Health?

- 3 lifestyle behaviors (poor diet, lack of exercise, smoking) cause 1/3rd of US deaths; 50% Americans have 1 or more chronic diseases; age of onset getting younger.
- mHealth apps allow care support/data collection 24x7--chronic disease prevention/management/research as part of daily life
- affordability/adoptability could support groundswell of medical discovery, evidence-based practice about treatment/prevention

vision: support individuals, communities, clinicians to continuously improve patient-centered, personalized, health and healthcare

mobile devices offer proximity, pervasiveness, programmability, personalization

Whose mHealth?

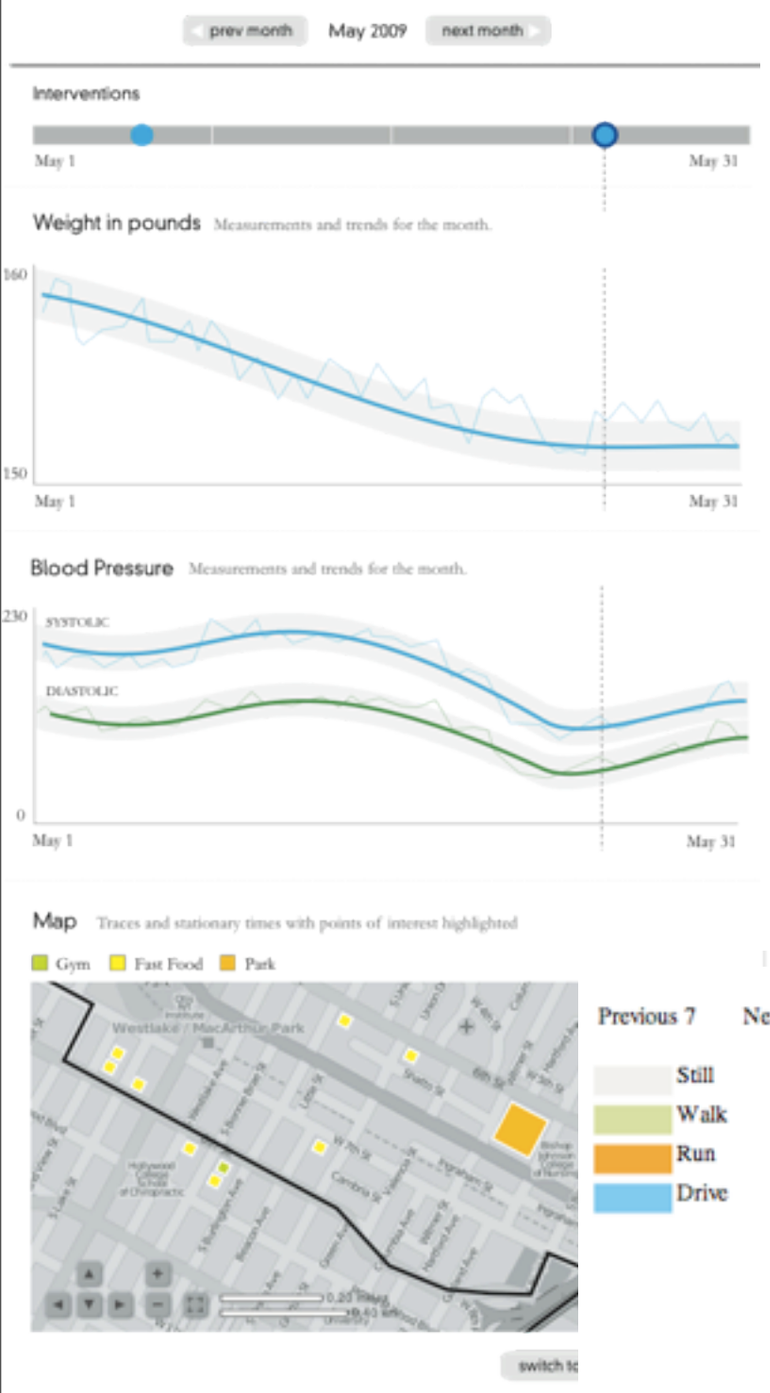
- **A woman who is pre-diabetic** tracks how eating/exercise habits affect weight and fatigue; also explores effective, comfortable blood pressure Rx dosage.

- **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*



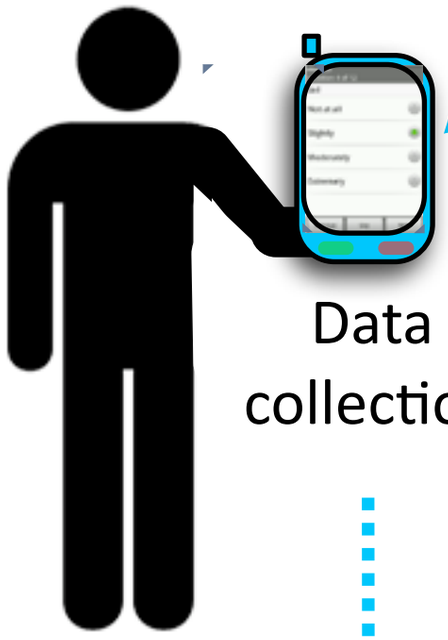
Automatically prompted, geocoded, uploaded, analyzed:

- 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

Ohmage system built to explore ***participatory*** mHealth



Data collection

Internet

Location and time triggered surveys

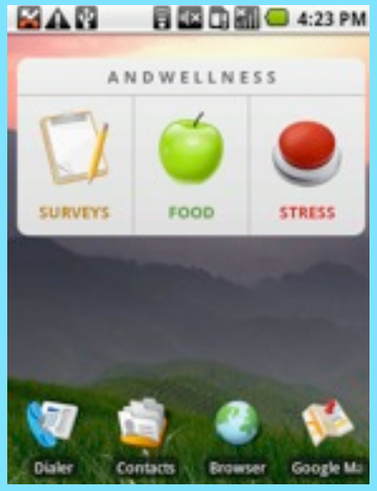
Multiple choice
Scale
Free text
Exercises

Automated capture

GPS, Wifi Accelerometer

Actigraphy, Mobility

Phonetop Buttons



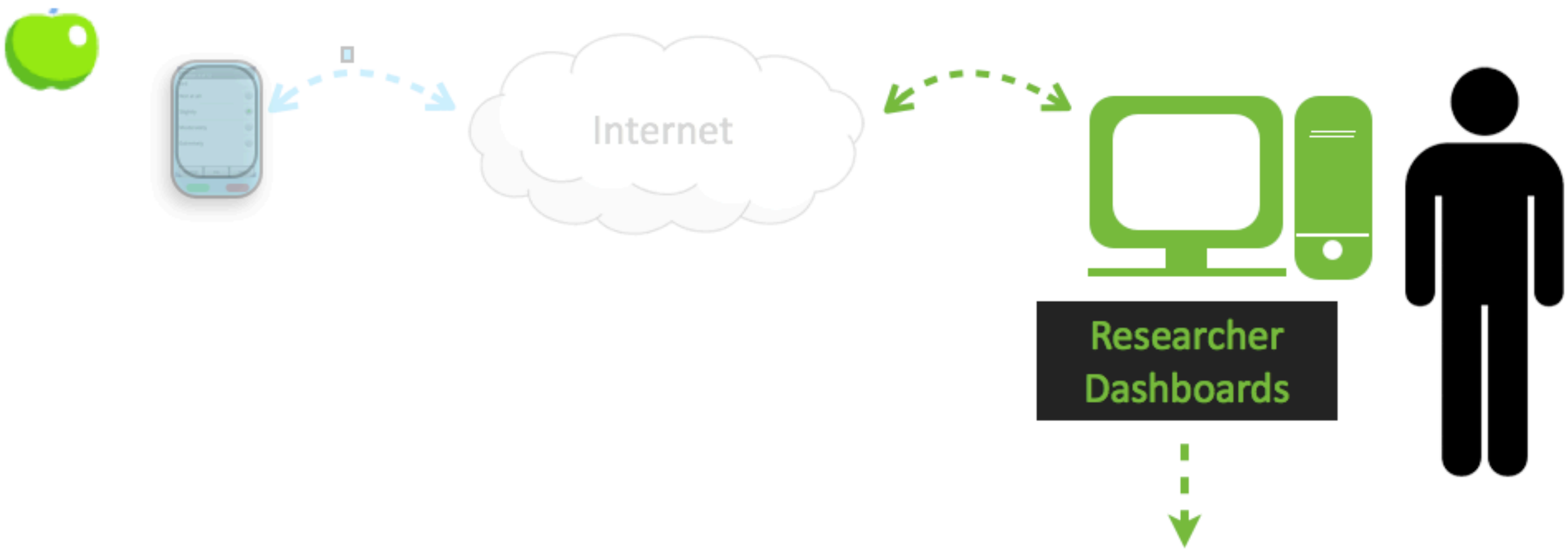
Phone-based activities

Games
Assessments
Exercises
Interventions

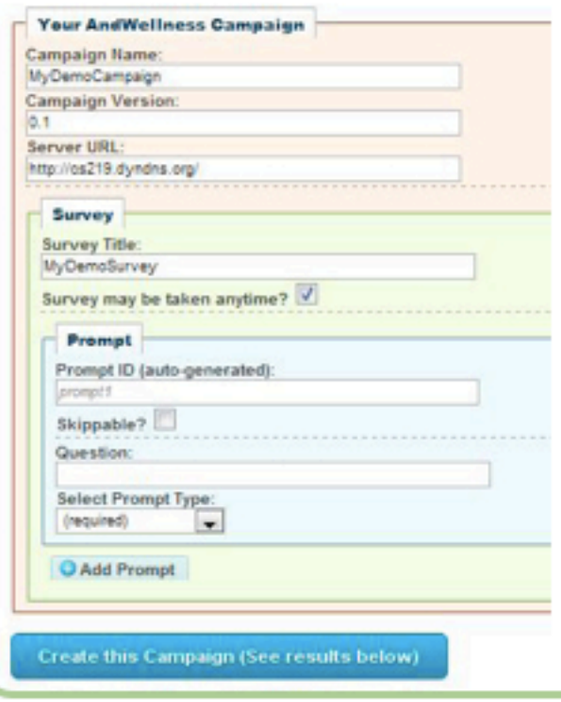
Many common mechanisms apply across mHealth applications

Ramanathan, Selsky, et al

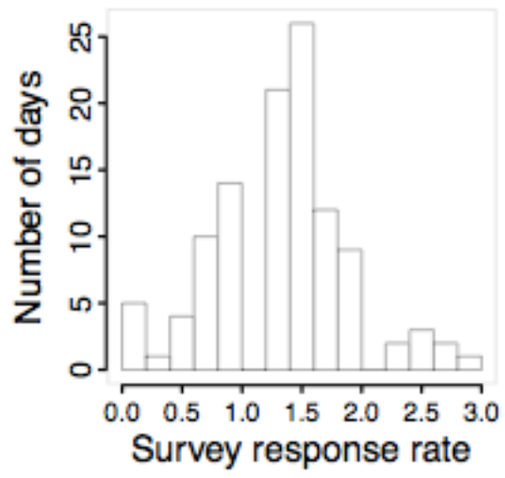
Support systematic shared learning through methods and tools used across many conditions, populations, investigations



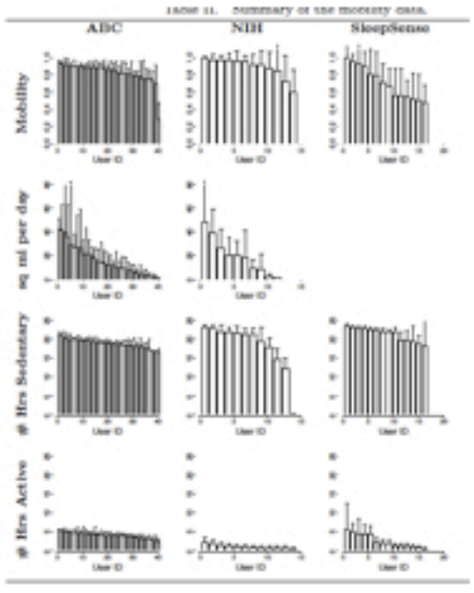
Survey Creation



Participation



Population Statistics



Ramanathan, Selsky, et al

Participatory design: functionality shaped by focus groups, interviews

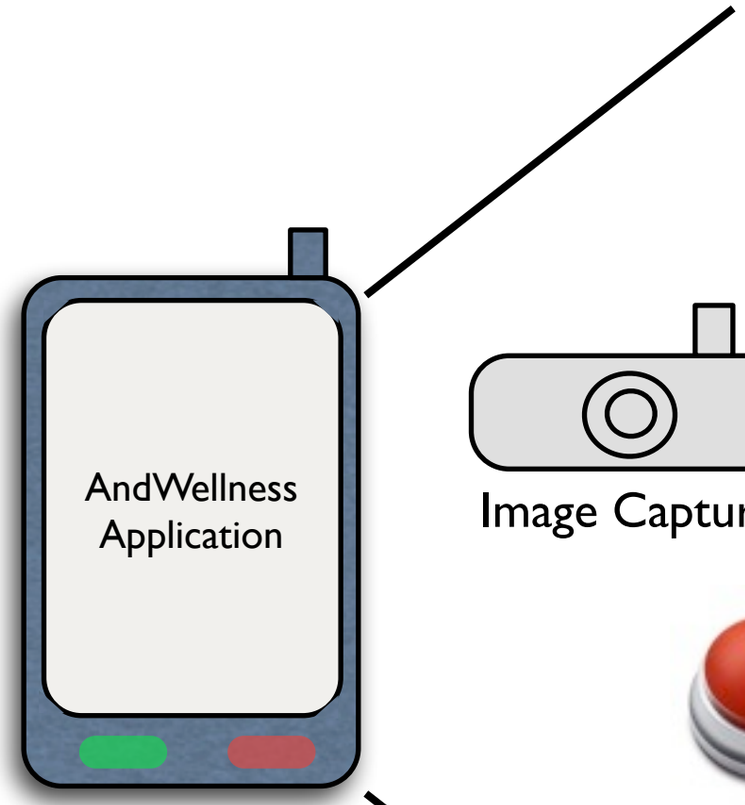
Trigger Authoring

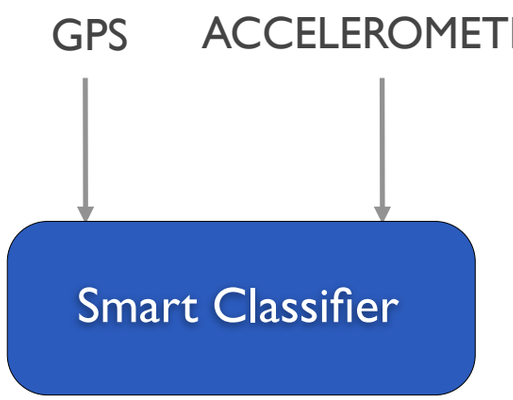
trigger logic as function of location, time, activity, prompt responses

Server

Survey Authoring

```
<survey>
 <title>Alcohol</title>
 <prompt>
 <text>How many drinks did you have today?</text>
 </prompt>
</survey>
```





Actigraphy

Image Capture

Stress, Eating Buttons

Survey Input

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

Ramanathan et al

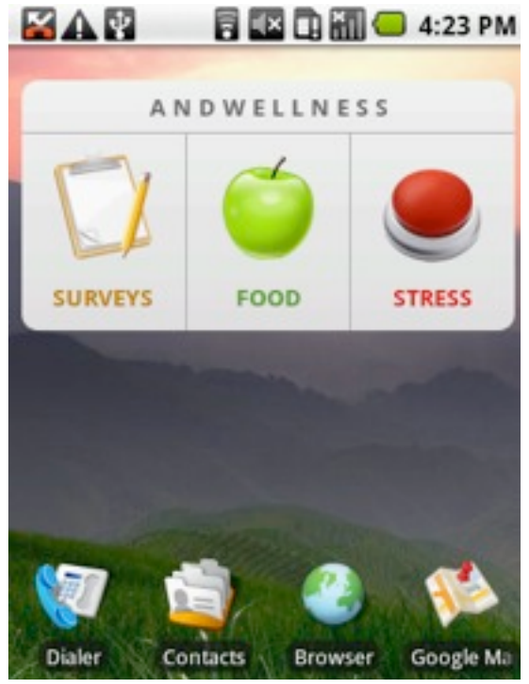
Focus groups summary (n=72)

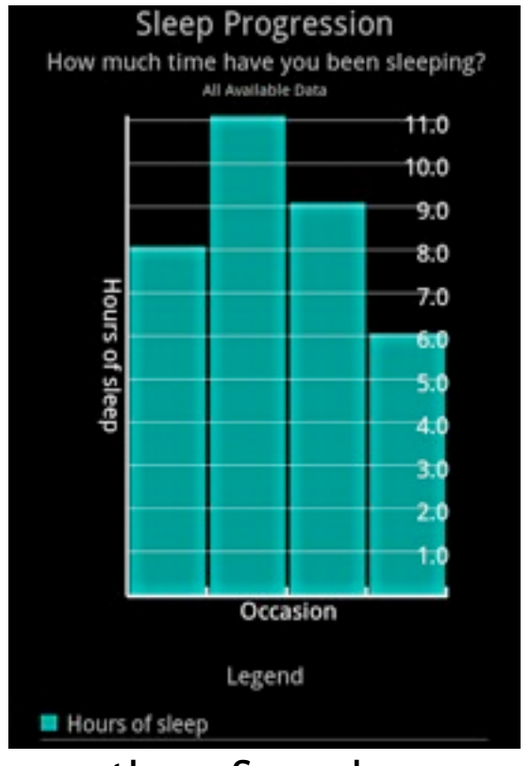
Population	Primary application features discussed
Young Moms n=23	<u>*Engaging participation without increasing user burden*</u> • Customization of reminder times/locations for convenience • Image capture of food to increase accountability • Set, manage, and monitor progress towards a goal • Light-weight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

Ramanathan, Swendeman, Dawson, Estrin, Rotheram-Borus

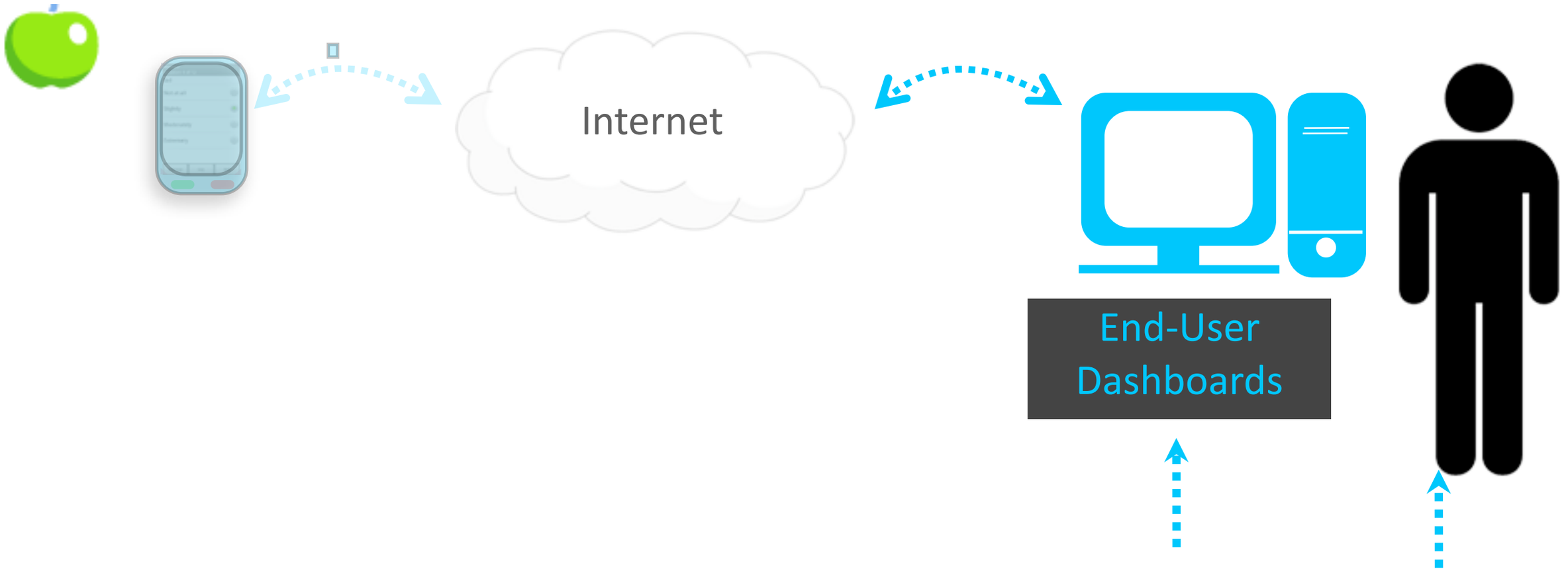
Notable feature requests

- **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.

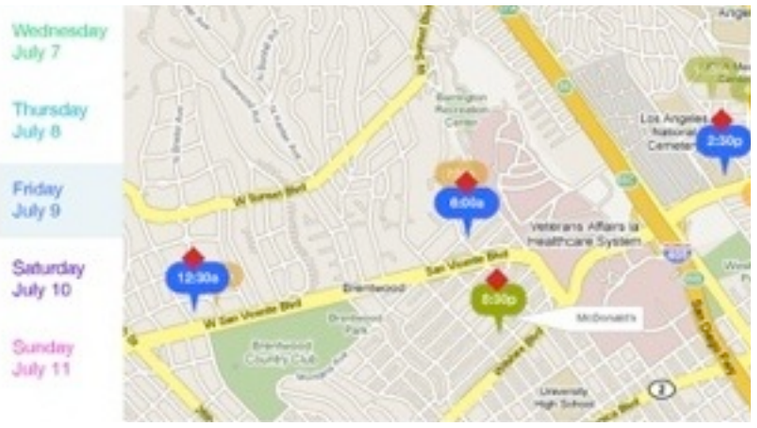




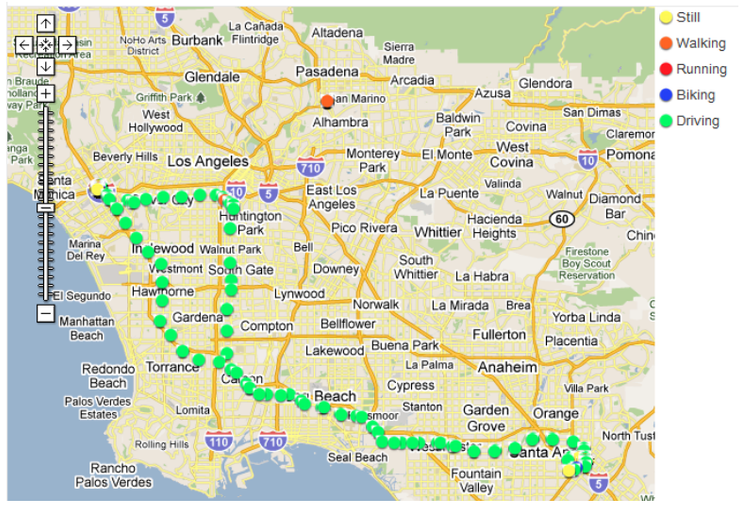
Ramanathan, Swendeman, et al



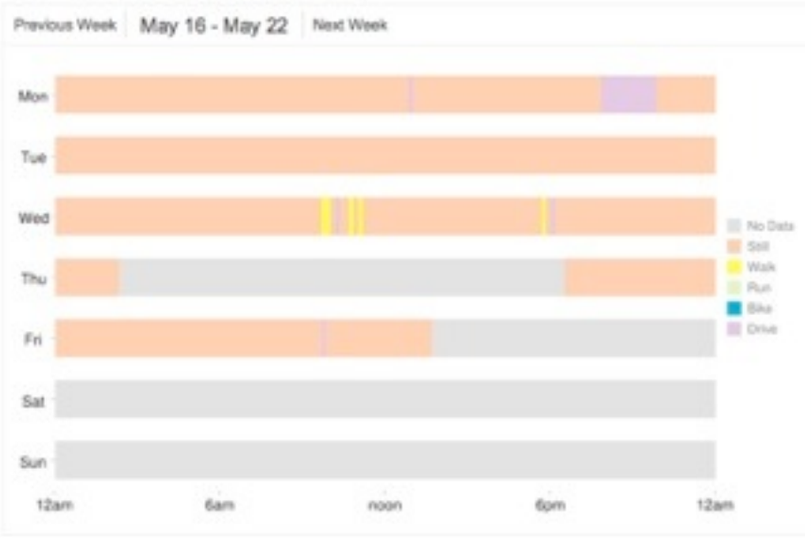
Correlations in time and space



Actigraphy over space

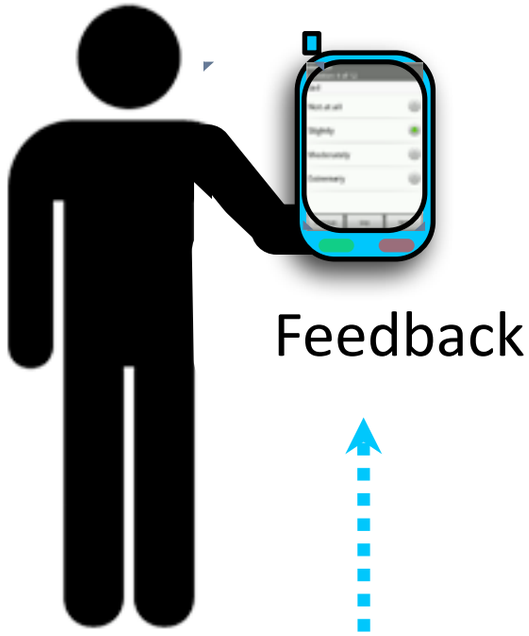


Actigraphy over time



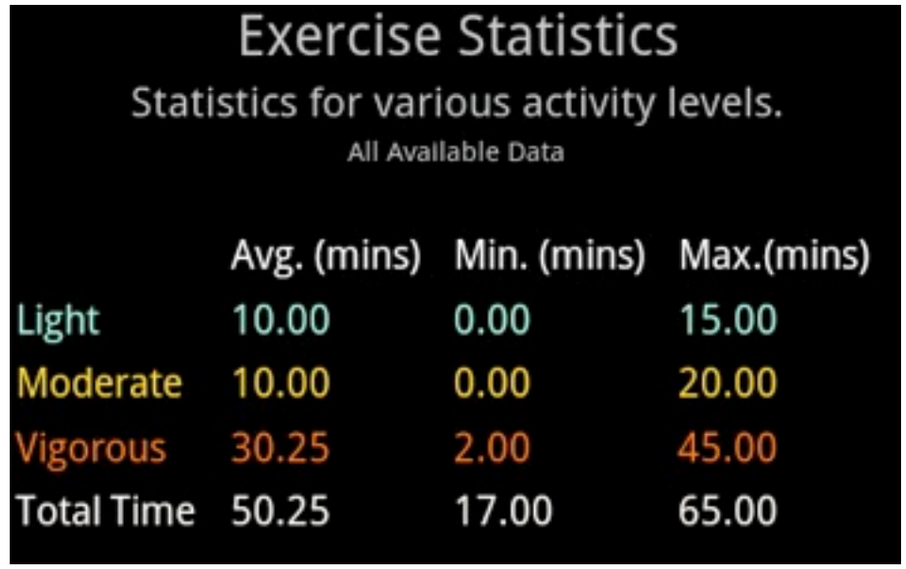
Work in progress for future release: time delayed correlations and correlations across behaviors

Ramanathan, Selsky, et al



Configure

Table Summaries

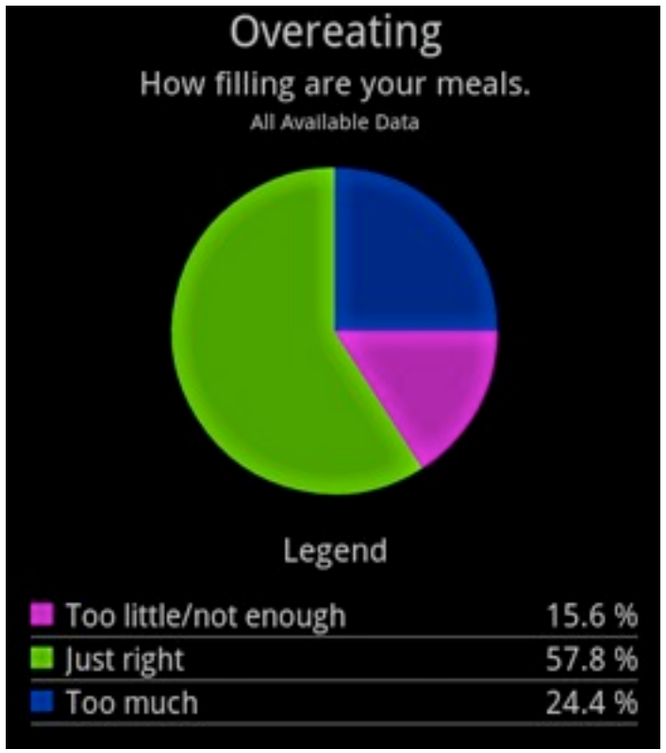


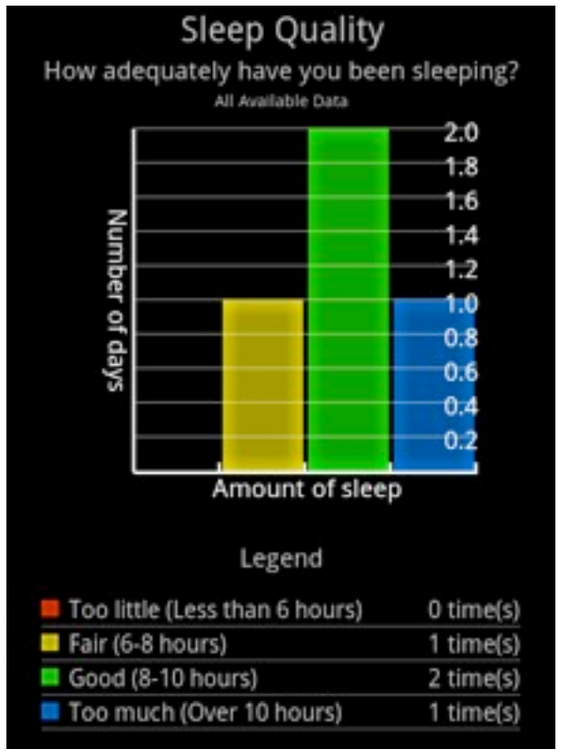
Exercise Statistics

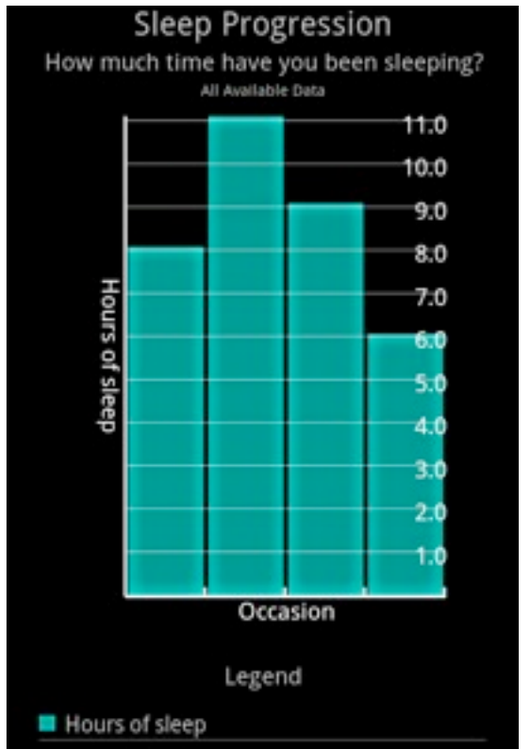
Statistics for various activity levels.

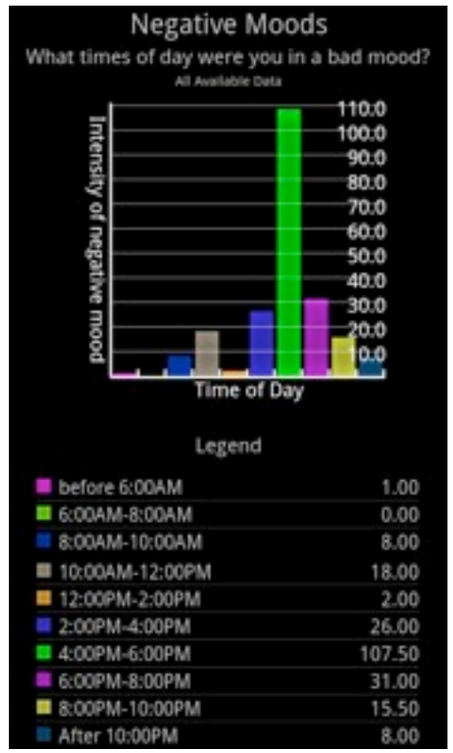
All Available Data

	Avg. (mins)	Min. (mins)	Max.(mins)
Light	10.00	0.00	15.00
Moderate	10.00	0.00	20.00
Vigorous	30.25	2.00	45.00
Total Time	50.25	17.00	65.00









* To Be Released August, 2011

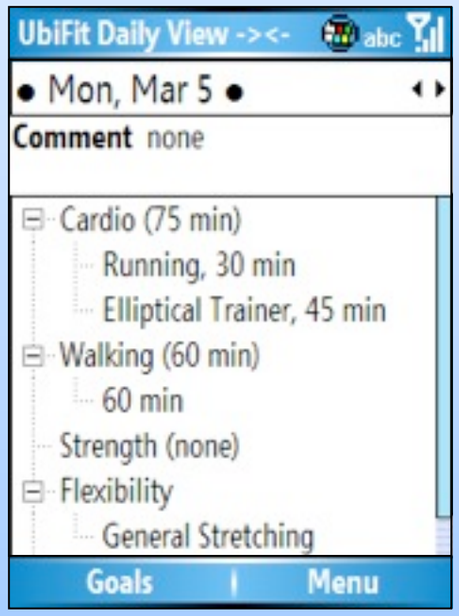
Chart Summaries

Iyer, Ramanathan, et al

Of course...“feedback” should look more like this and be tailored to individual participants-- *Ubifit (UW, Intel)*

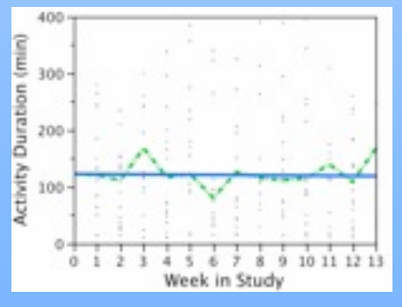
ubifit garden

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

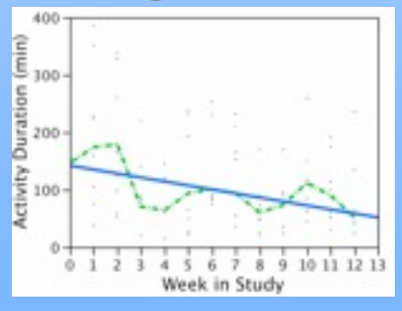


participants who...

had the garden

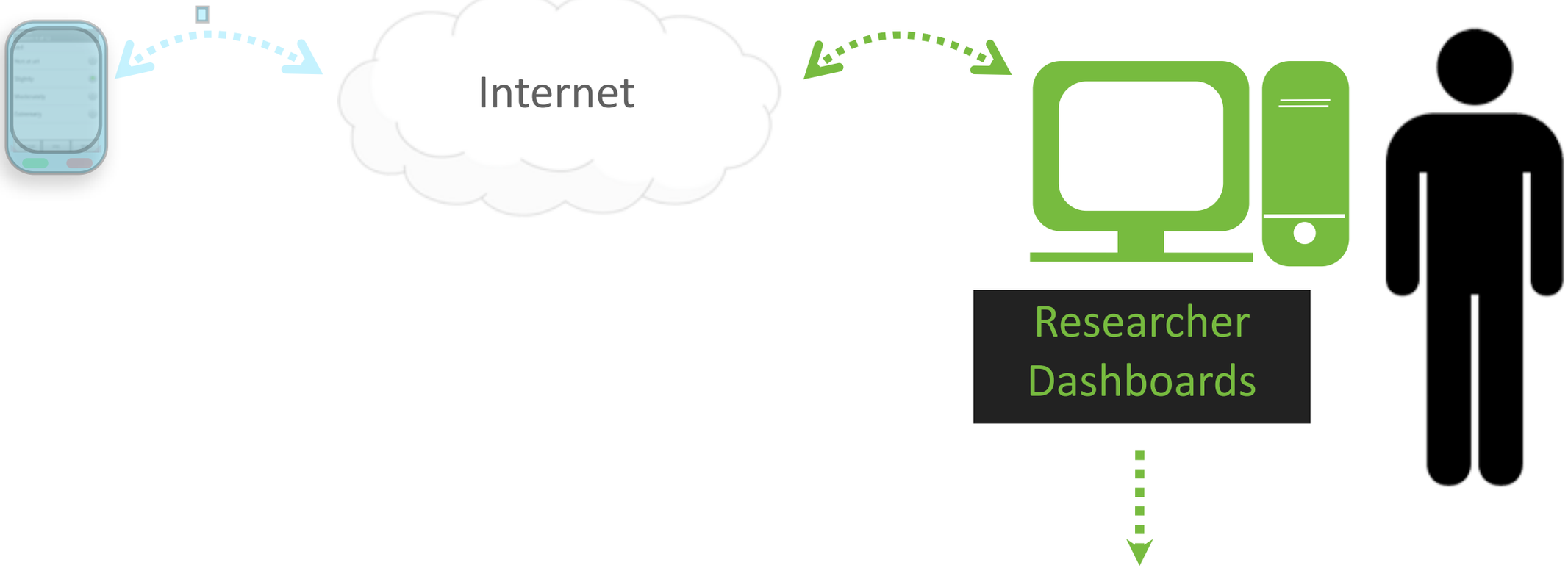


did NOT have the garden

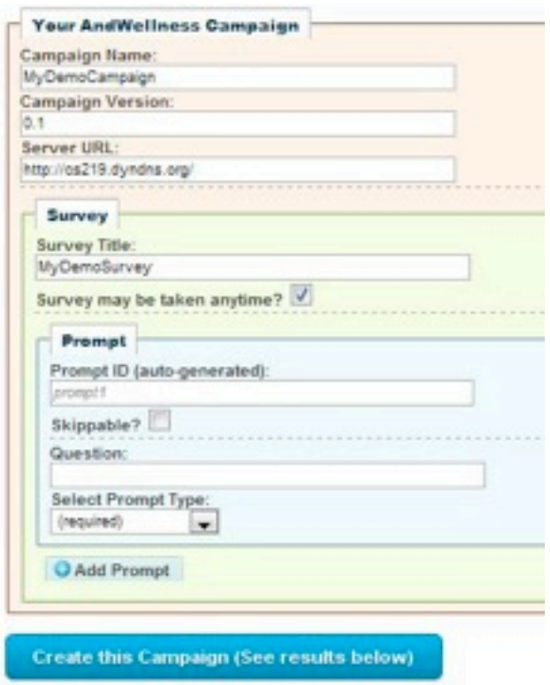


[1] intel research seattle
[2] dub, u of washington

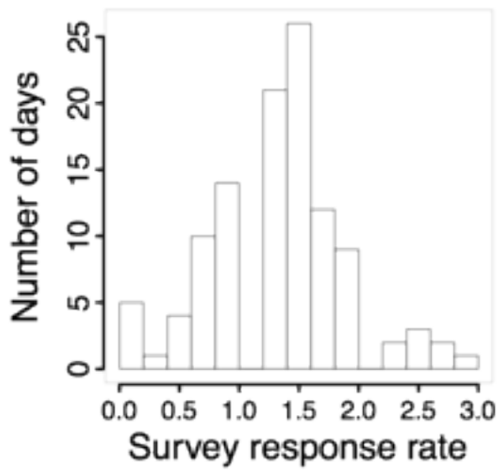
consolvo, mcdonald, landay, chi 09 ❁ consolvo et al, ubicomp 08 ❁ consolvo et al, chi 08 ❁ choudhury et al, ieee pervasive mag ‘08 ❁ froehlich et al, mobisys ‘07 ❁ consolvo, paulos, smith, mobile persuasion ’07



Survey Creation



Participation



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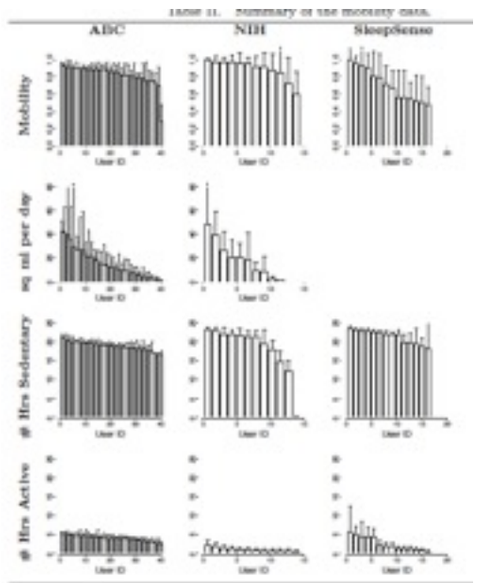
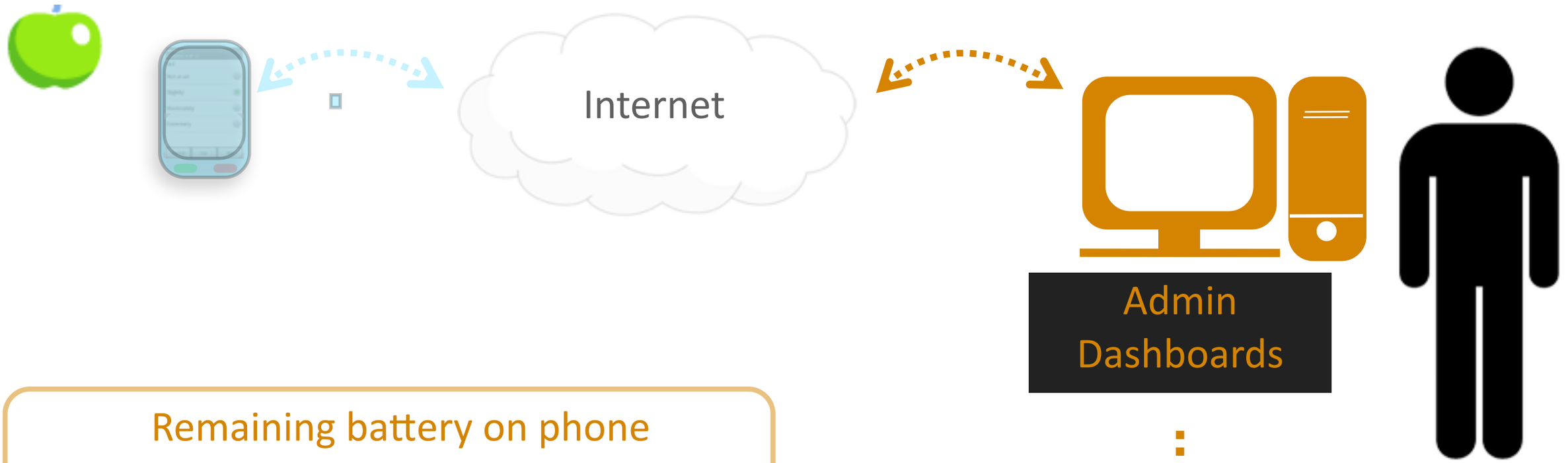
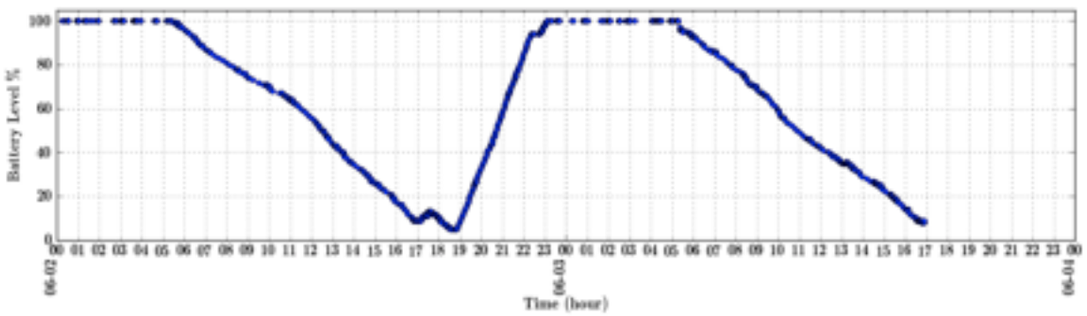


* in progress for release, Dec, 2011

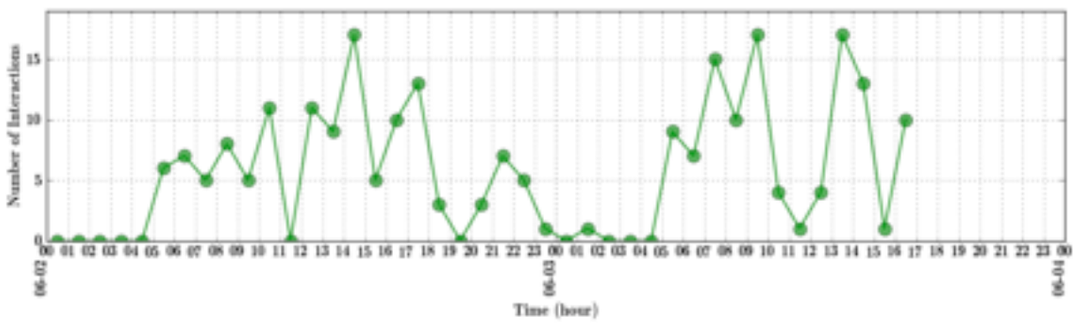
Ramanathan, Selsky, et al



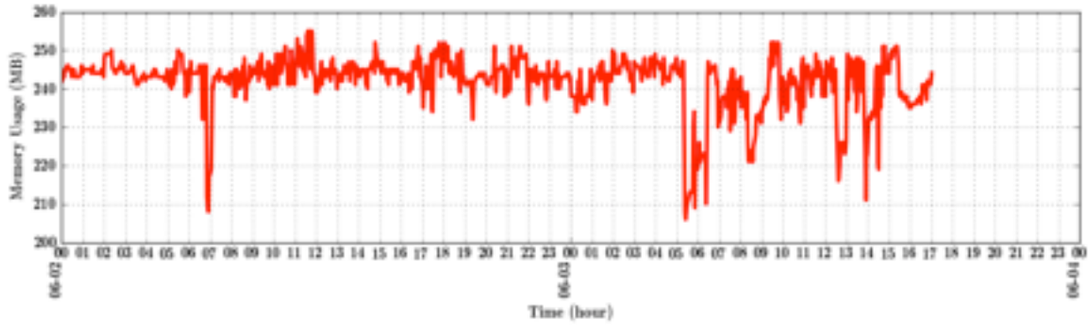
Remaining battery on phone



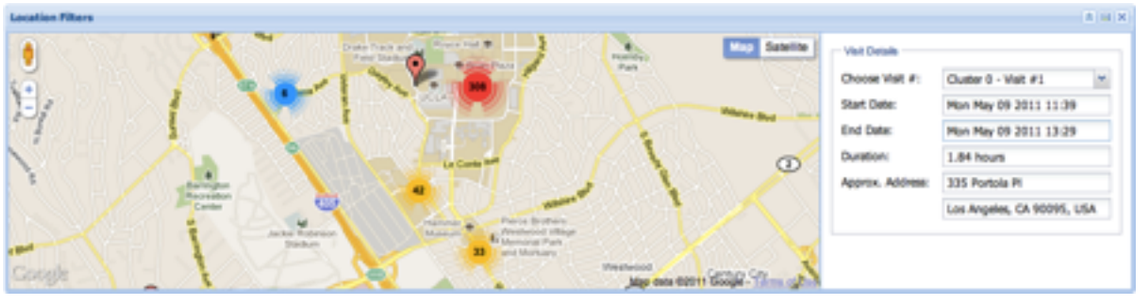
User interaction with phone



Memory usage on phone



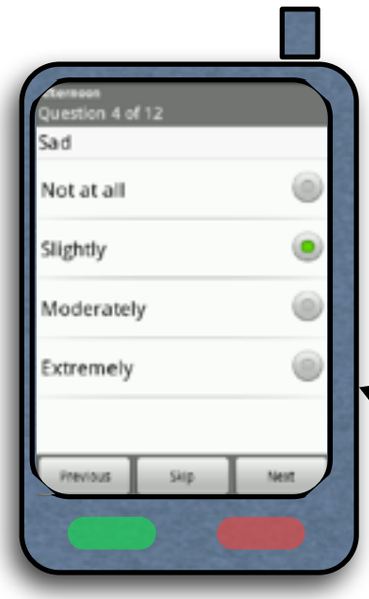
Filter by location, time, user



Wu, Falaki, Estrin, Ramanathan

Ohmage system implementation

Smartphone



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

JSON/HTTPS

Internet

Server

andwellness.org

Java 6 + Tomcat 7 + MySQL 5.1

RApache for datavis

JSON/HTTPS

AndWellness

Web Browser Clients

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%)

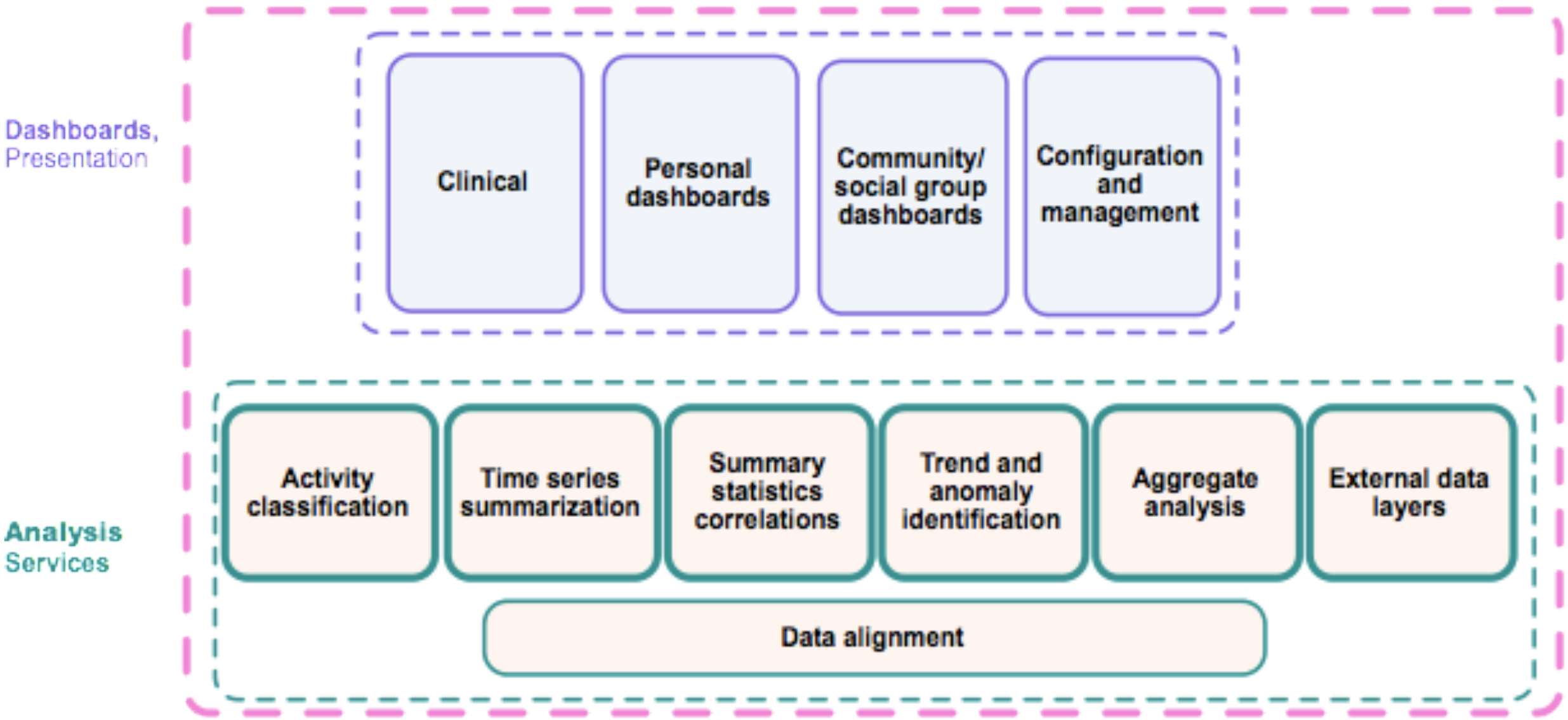
- Open mHealth innovative ecosystem and methodologies (15%)
- Participatory privacy policies and mechanisms (15%)

Key *research* challenges

- <u>Health sciences community:</u>
  - 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
- <u>Technical community:</u>
  - 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**

InfoVis

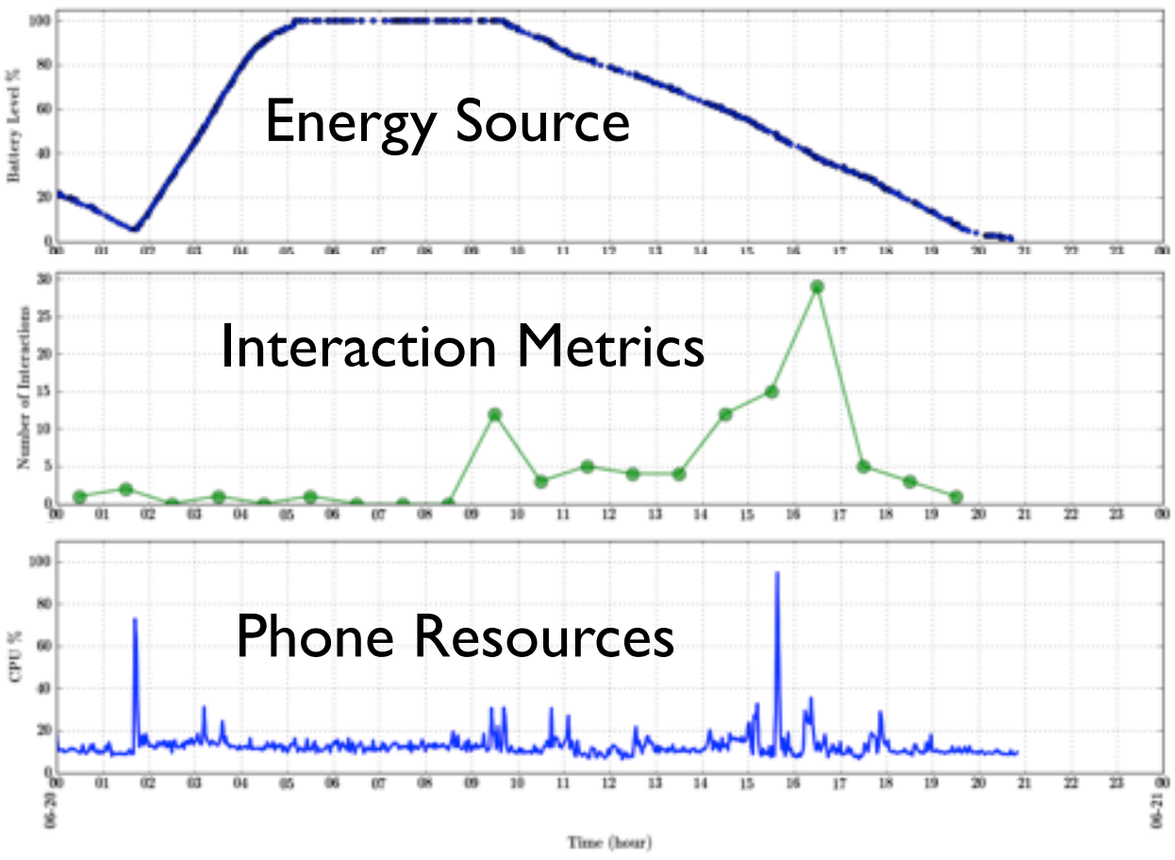
extract and present relevant trends, patterns, anomalies, correlations across diverse data streams and to diverse audiences

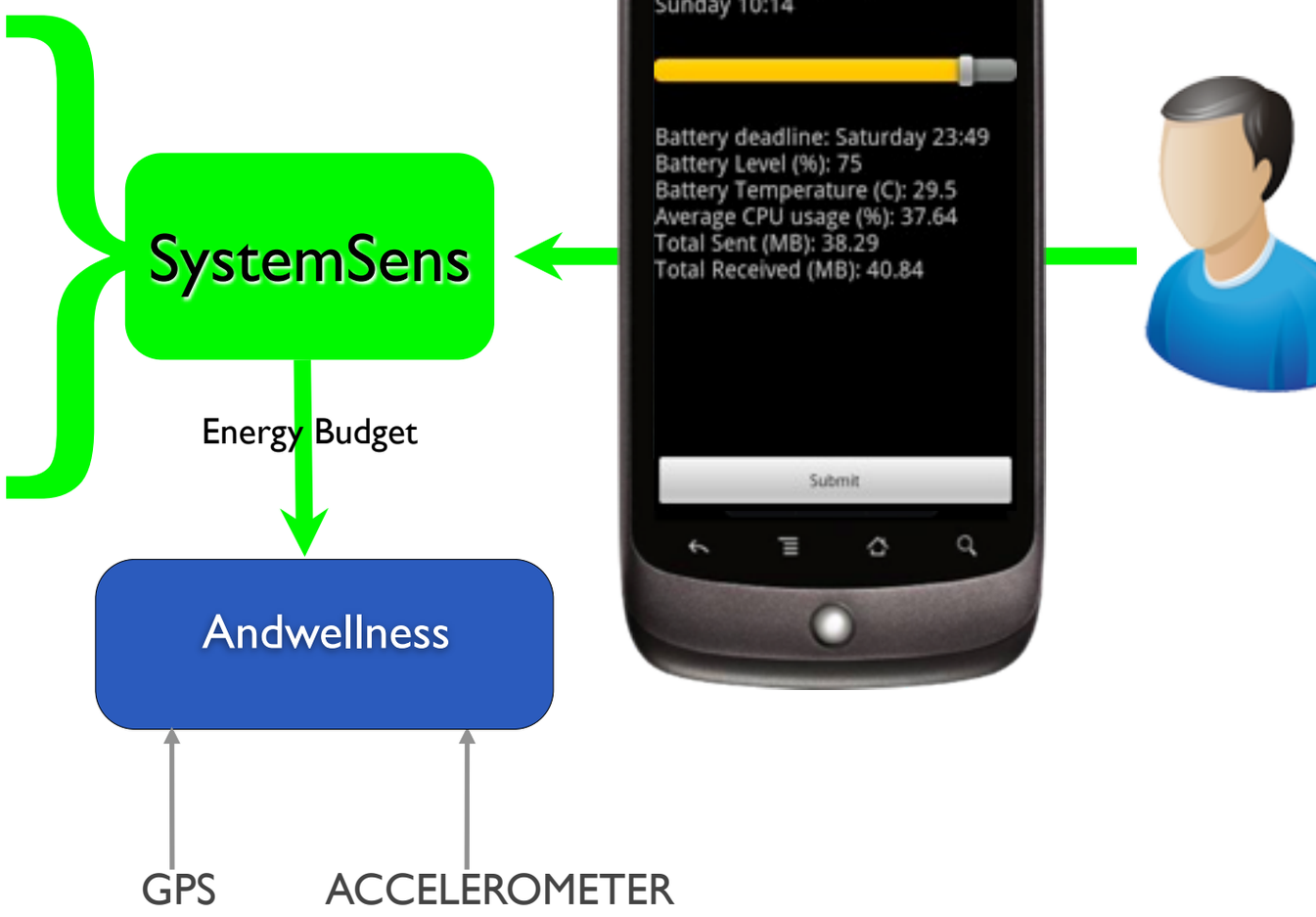


Needs: pre-processing, feature extraction, integration with machine learning libraries and statistical analysis tools, incorporation of external datasets, geo-spatial analyses, informative and configurable presentation

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

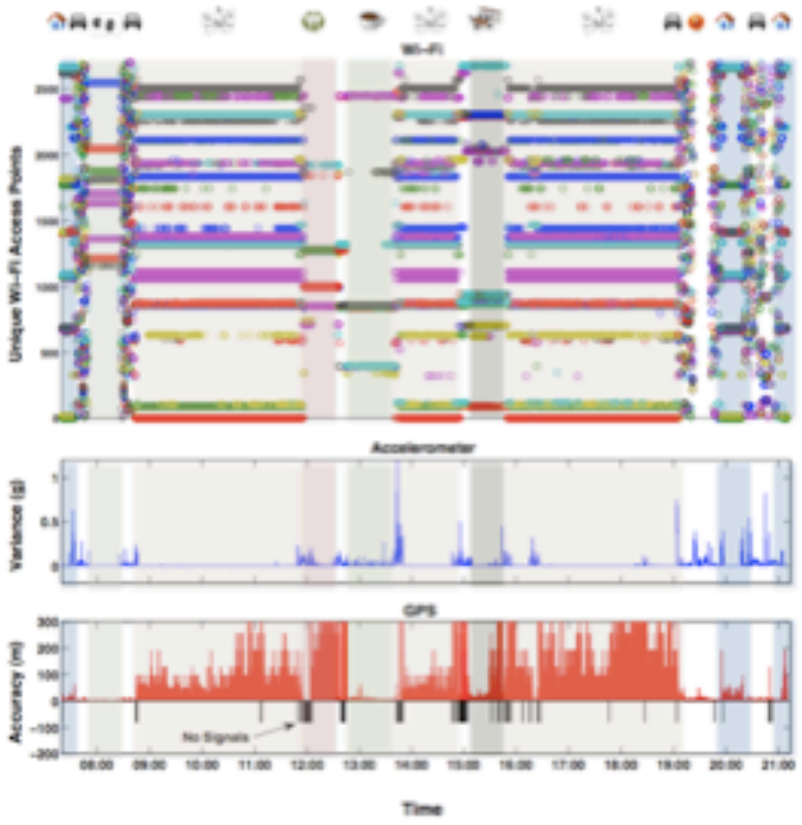
Semantic places and paths

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

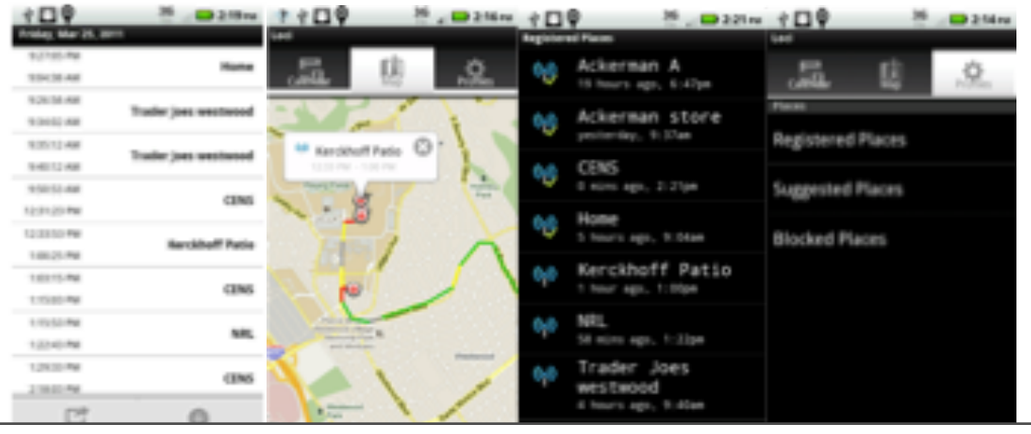
- people spend approximately 89% indoors, 5% in a vehicle, and 6% at outdoors on average



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

Many power saving opportunities exists when the device is immobile

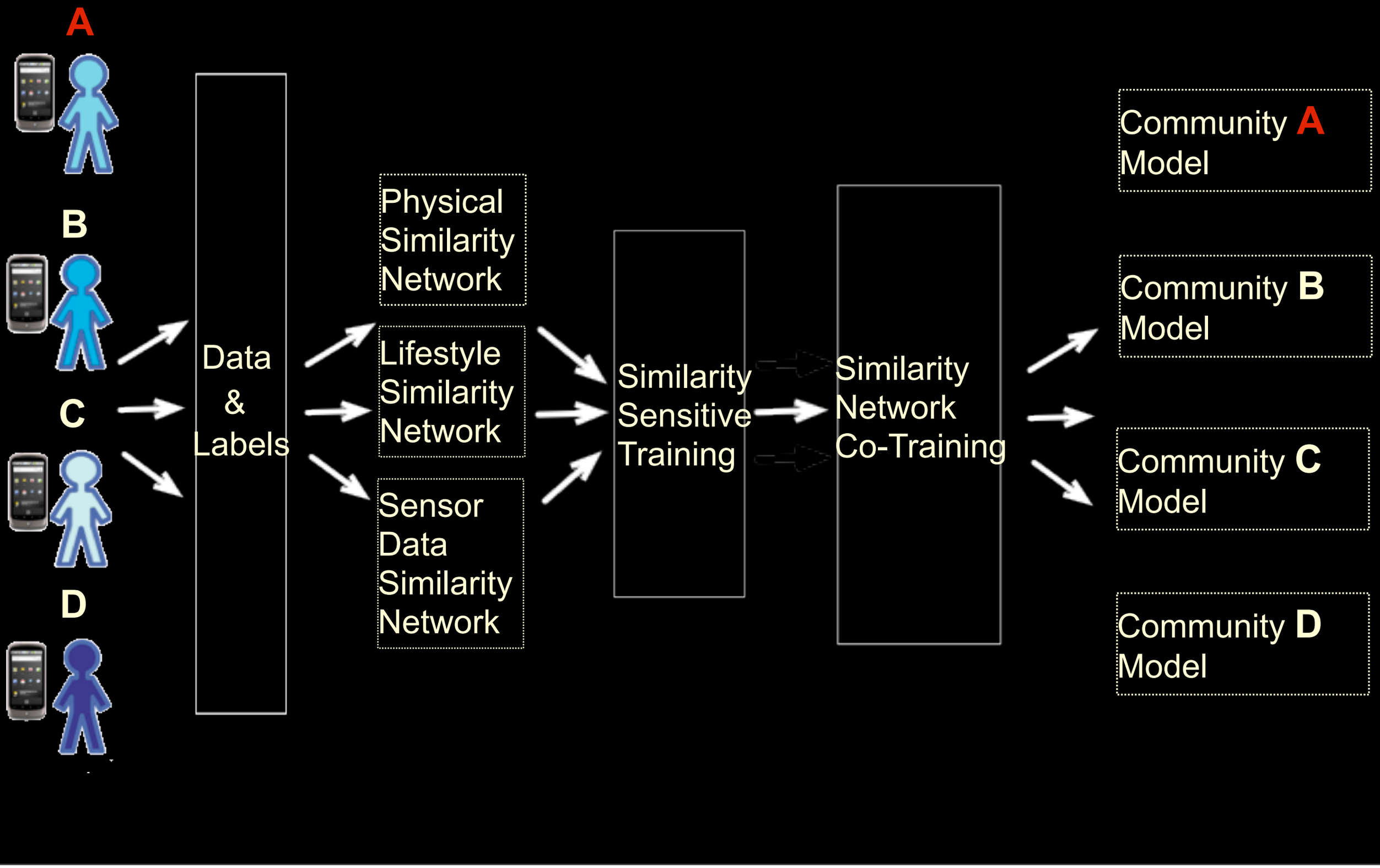
GPS position fixes are inaccurate most of the time but informative when traveling paths connecting places



Sensor traces from a single day following a normal routine

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

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

Personal Data Vault

- User Identity and Authentication

- Long-term Data Management

Patient defined selective sharing with Open mHealth Server function

Third Party Services

- Analytics for Personal Data Streams

- Interface to Clinical Care Plan, Personnel

- Integration with EHR/PHRs

- Cross Patient Aggregation

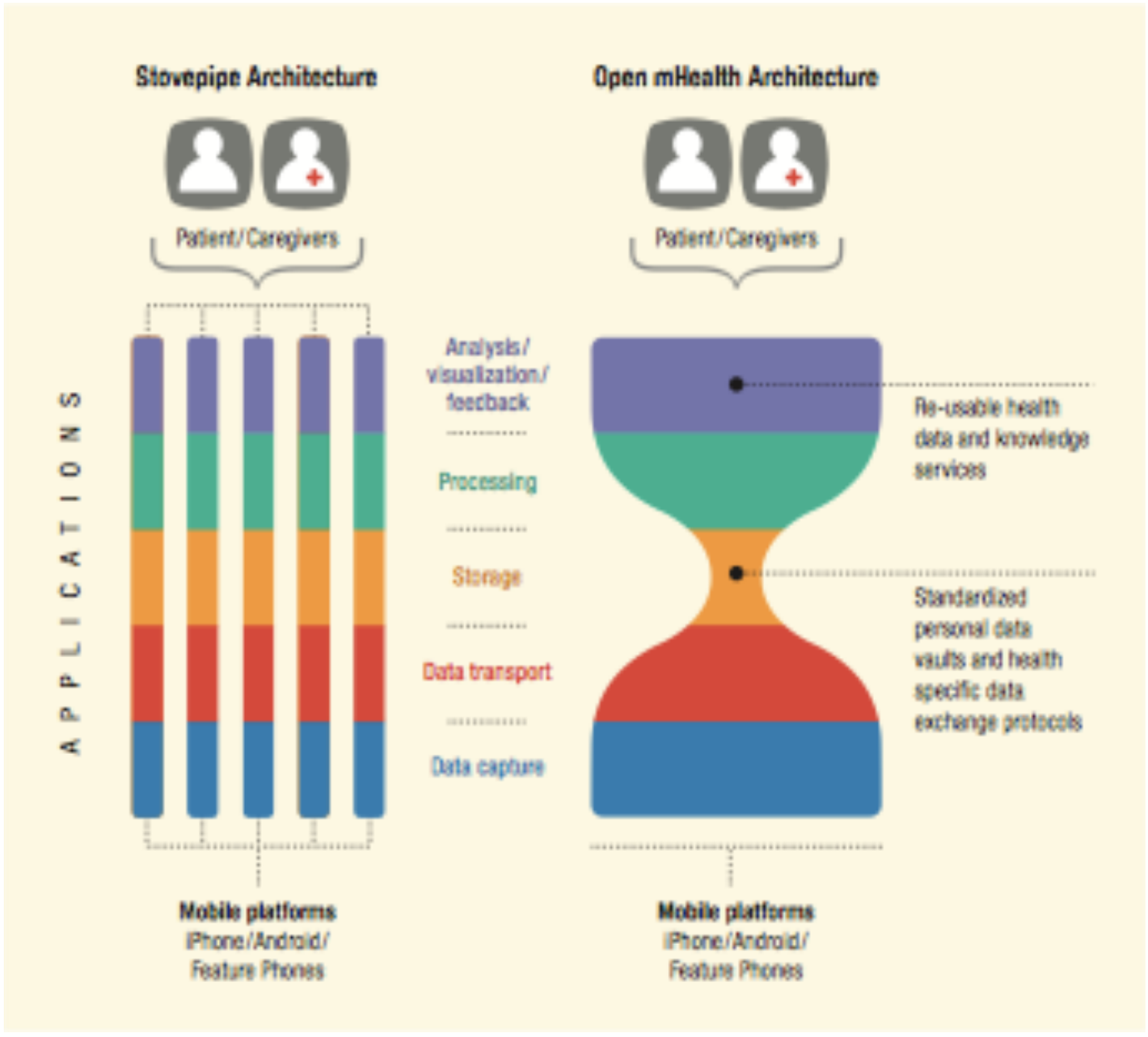
Well defined interfaces allow analytics functions to be mixed, matched, shared, compared

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

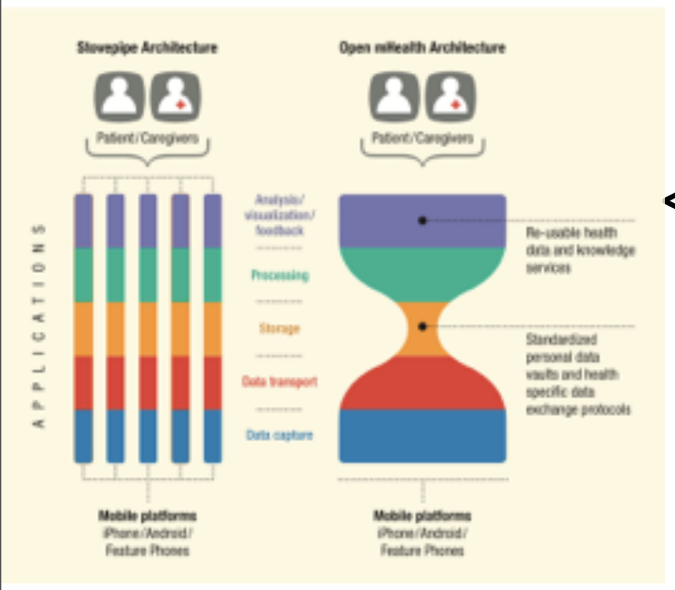
Why focus on open architecture ?

broad applicability (diseases, demographics), heterogeneous/‘dual’ use (engagement, treatment, evidence), need for innovation ecosystem to support evolving methodologies and evaluation

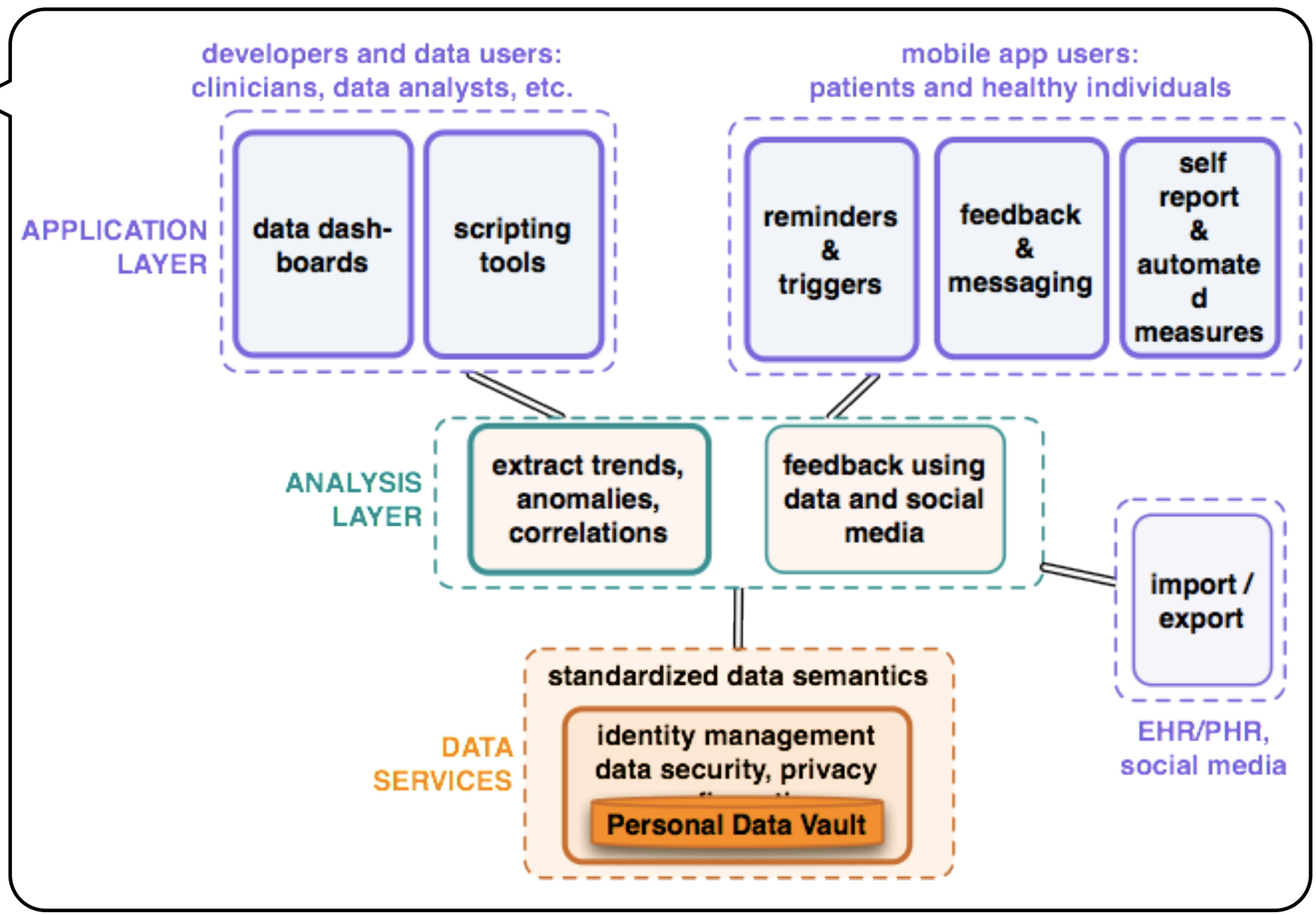


Meaningful mHealth requires more than just a mobile app

authoring prompts and triggers; individual feedback and tailored messaging; analysis and visualization; personal data vaults



http://openmhealth.org



Swiernik, Estrin, Sim, et al

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

Summary: promote innovative infrastructure with *Modularity, Sharing, Analytics, Iteration*

- **Modular** components with well defined interfaces allow innovation to occur in a decentralized, parallel, and asynchronous fashion; with broad participation and rapid iteration.

- Architectures that are **shared** by large communities benefit from economies of scale and shared learning so that all the boats float higher and the state of knowledge and state of available tools improve exponentially instead of just linearly.

- Systems that leverage their digital nature to continually collect data on usage and behavior can use these **analytics** to adapt and improve and correct in realtime (or at least relevant time).

- The technology makes feasible data collection and interventions that previously could not be realized with real people in the course of their real lives. Because of this novelty, health experts should work alongside technologists and statisticians to **iteratively** design, deploy, evaluate, and adapt mHealth innovations.

Closing remarks (aka parting shots)

"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.

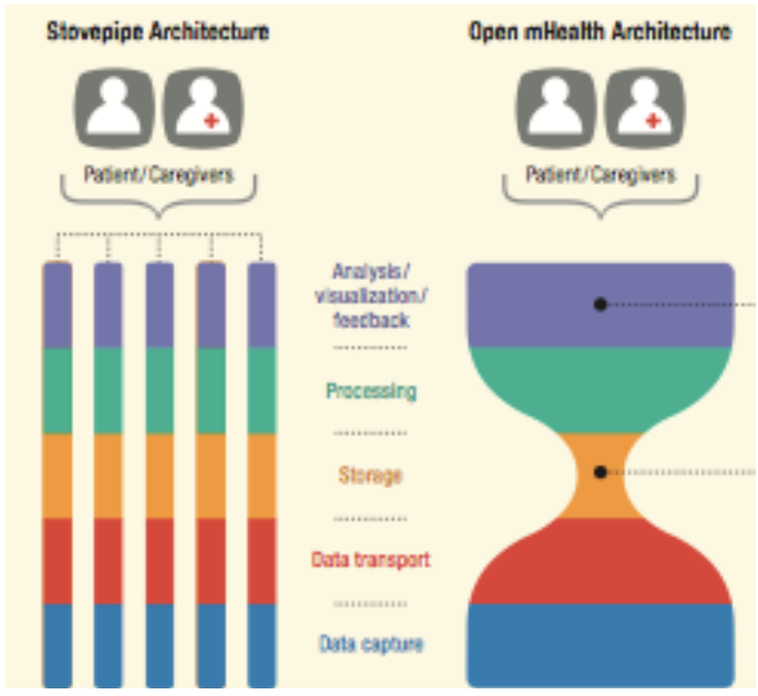
The same can be done for global health. Government, commercial, and nongovernmental entities involved in health IT and innovation should cooperate to define and instantiate architecture, governance, and business models and to steer initial mHealth investments into open architecture."

- D Estrin, I Sim. Open mHealth Architecture: An Engine for Health Care Innovation. Science Magazine, Nov, 2010.

Summer reading recommendations:

The filter bubble, Eli Pariser

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



Open mHealth initiative: http://openmhealth.org

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Collaborators

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