Performance Targets for Wearable $PM_{2.5}$ Sensors in Epidemiological Studies (of Pediatric Asthma) Using Real-Time Enabled Informatics Platforms

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Outline

- Setting the context
  - Personal exposure monitoring in environmental health sensor-based epidemiological studies (exposures to health effects)
  - Los Angeles PRISMS Center informatics platform for pediatric asthma
- $PM_{2.5}$ measurement performance targets
  - Priority depends on research question
- Essential features and design recommendations for next-generation wearable $PM_{2.5}$ sensors for longitudinal epidemiological studies

Los Angeles PRISMS Center

PI Alex Bui (UCLA)

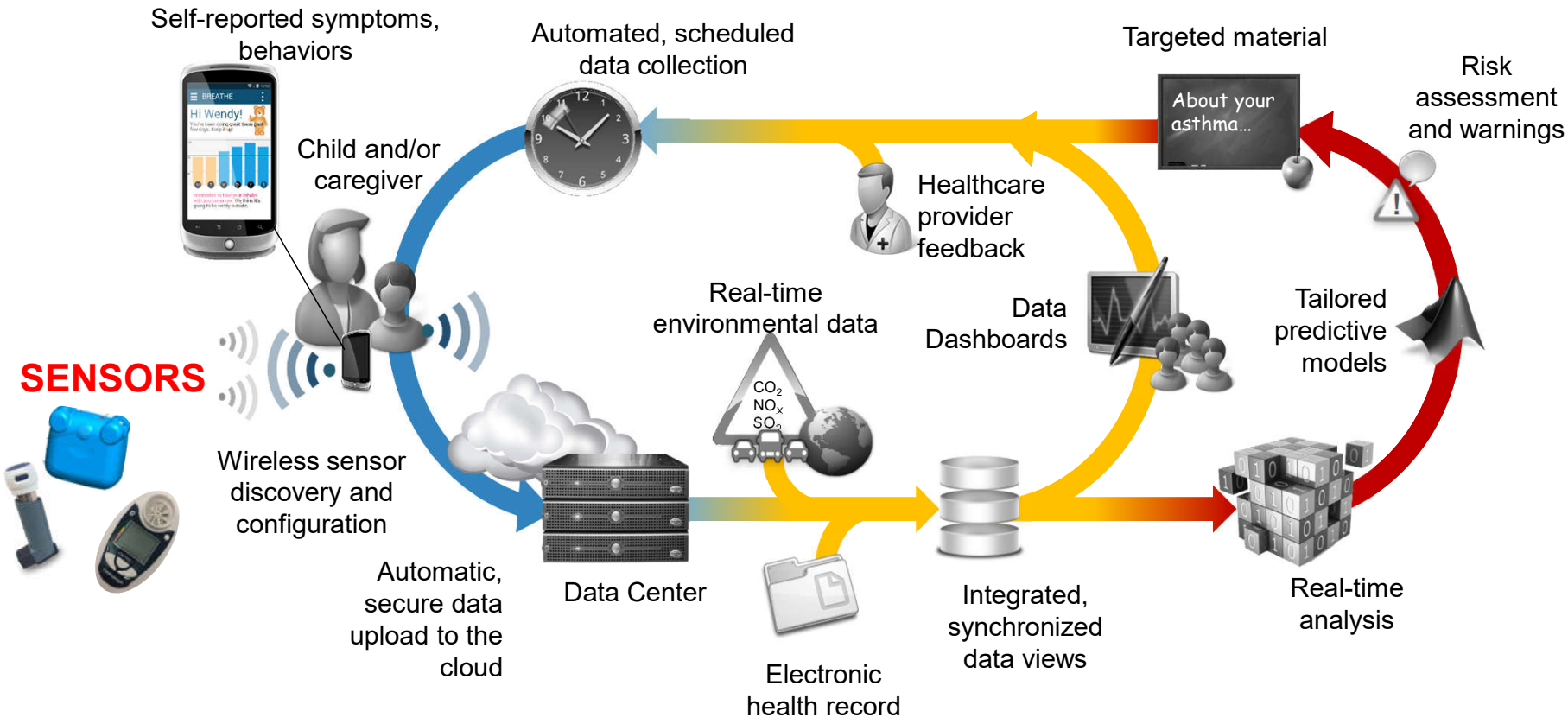
Project 3, Real-Time Air Pollution and Asthma Study

PIs Habre and Gilliland

The Los Angeles PRISMS Center

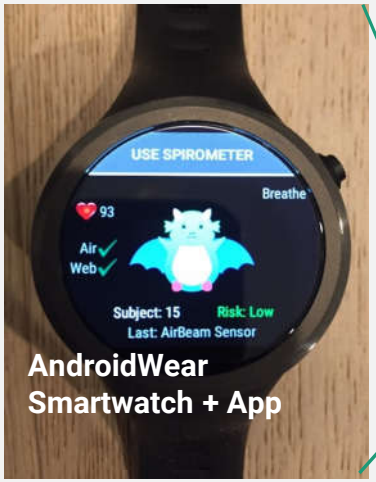
- Building a sensor-based informatics platform to measure personal exposures (low-cost sensors) and identify asthma triggers in children
- Individualized 'trigger discovery' at high time and space resolutions, looking at ***multiple*** environmental ***exposures*** (physical, chemical and biological - eg, mixtures), ***behaviors*** (eg, exercise, adherence to medication) and ***psychological*** (eg, stress) exposures ***in context***
- Advance scientific understanding of relationship between environmental exposures and asthma exacerbations at short time scales

The Los Angeles PRISMS Center BREATHE Informatics Platform for Epidemiological Studies of Pediatric Asthma

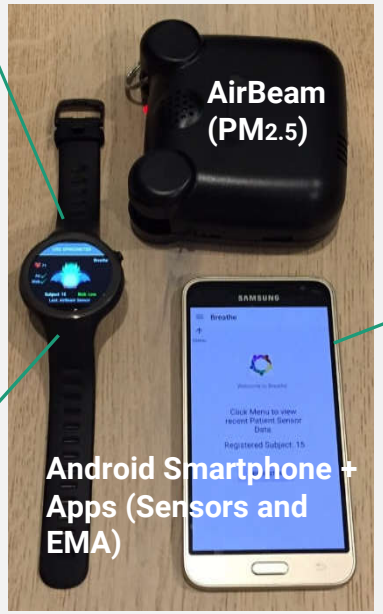


Informatics Platform for Personal Air Pollution Monitoring in Children

Breathe Kit, Los Angeles PRISMS Center

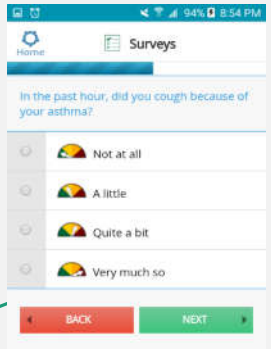


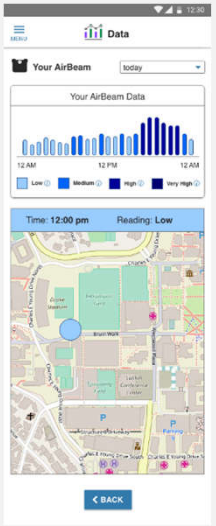
AndroidWear Smartwatch + App



AirBeam (PM2.5)

Android Smartphone + Apps (Sensors and EMA)

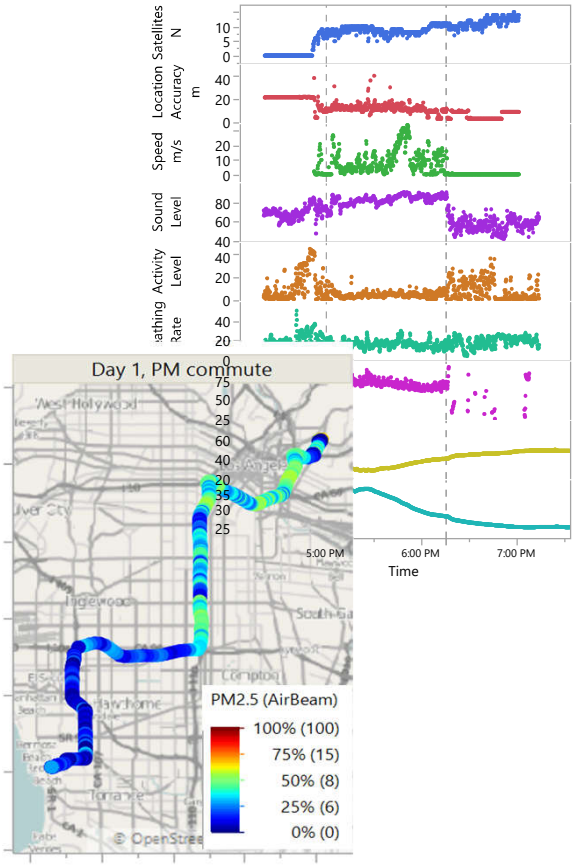




Ecological Momentary Assessment (EMA) Surveys + mobile dashboards

Inhaler

Spirometer



Collect exposure and health data at high spatial and temporal resolutions and investigate acute asthma triggers

BREATHE Kit: Biomedical REAl-Time Health Evaluation

$PM_{2.5}$ Sensors and Real-Time Enabled Informatics Platforms

- Retrieve, process and store data in real-time
- Integrate minute-level $PM_{2.5}$ exposure with geolocation, microenvironment, time-activity, behaviors, wear compliance, etc..
- Context-sensitive data collection
- Real-time visualization and communication of data
  - Participant engagement
  - 'Actionable' information, decision-making
- $PM_{2.5}$ sensor becomes *part of an informatics platform or system* collecting information on participants' behaviors, location, and exposures
- Enhances ability to research acute health effects *in context* (more representative of real life) and inform risk communication

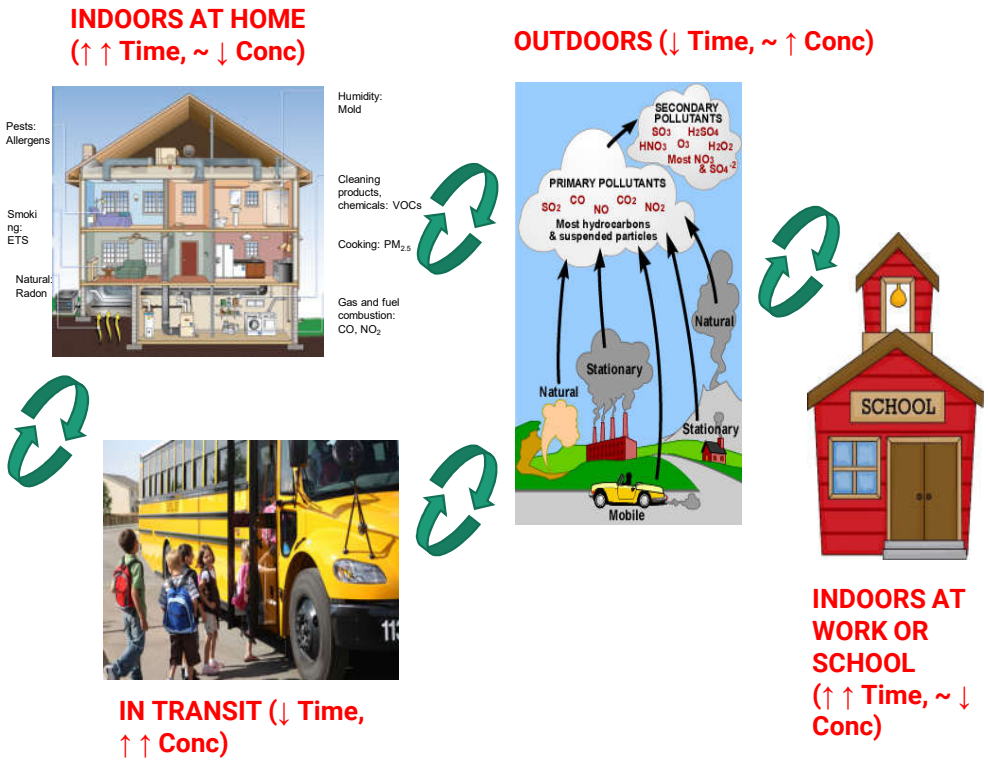
Performance Targets for Wearable $PM_{2.5}$ Sensors in Longitudinal Epidemiological Studies of Acute Outcomes

Parameter	Selection Criteria
	As close as possible to equivalent FRM/FEM
Accuracy and precision	±15% or less
Interferences	Minimal
Data collection, storage, and retrieval	Internal storage, **wireless, secure and real-time** communication
Energy consumption	Minimal: **Battery life ~8-12 hrs** and/or **simple charging requirements**
Participant burden	Low: Low weight, low noise, unobtrusive form factor, **"wearable", flexible wear options**
Durability, known performance	Consistent and proven performance, **across microenvironments and mobility, low drift over time**

Courtesy of Andrea Polidori and the SCAQMD AQ-SPEC Program, modified

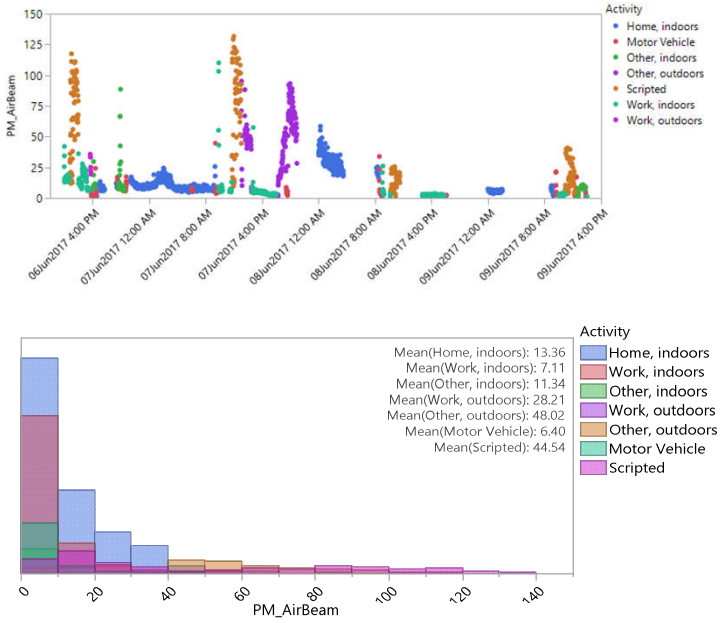
Mobility Across Microenvironments

- Lab and stationary, field evaluations > mobile evaluations
  - Standardized, scripted scenarios?
  - Geographic differences?
  - Complicated but important
- Hours to months > 5 mins to 1 hr time integration
- Relative humidity interferences especially important

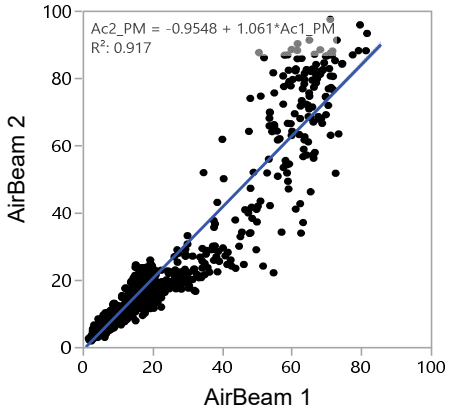


Example: Scripted Personal Exposure Scenarios

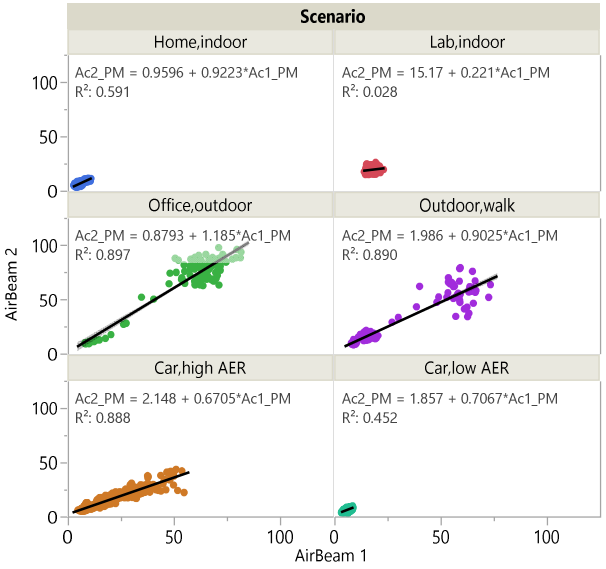
Highly variable concentrations across activities and microenvironments



Good collocated unit-to-unit agreement (Airbeam, 10-sec time resolution), highly variable by microenvironment (epi analysis implications?), also variable by particle size (data not shown)



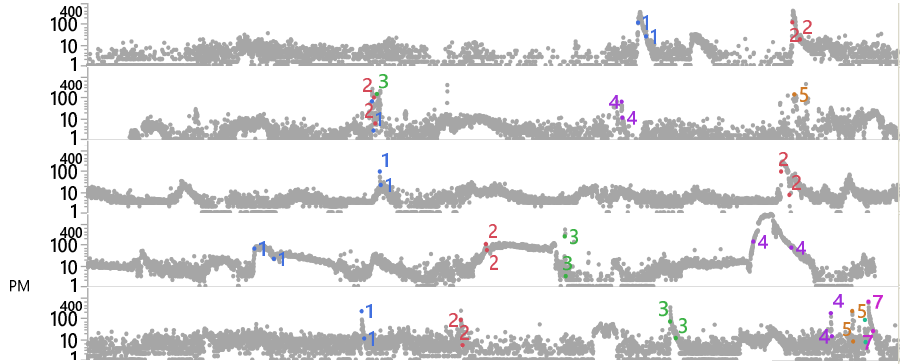
Overall



By Microenvironment

Context-Sensitive Data Collection around Real-Time $PM_{2.5}$ Measurements

- LA PRISMS example: Trigger survey 5 mins after detecting a $PM_{2.5}$ 'primary combustion' peak
  - Identify transient sources
  - Capture outcome at proximal time, minimize recall bias, evaluate peaks and sources as potential acute asthma triggers
- Crucial parameters:
  - Sensor response time and accuracy (same peak definition across participants), real-time



Item
Were you near any of the following just before the phone alert appeared?

Response Choices
Traffic (cars, buses or trucks)
Cigarette smoke
Vaping/e-cigarette vapor
Cooking or barbequing (BBQ)
Lit fireplace (burning wood or gas)
Space heater (burning fuel)
Burning candles or incense
Other smoke

What matters most? It depends on the research question…

Between-person

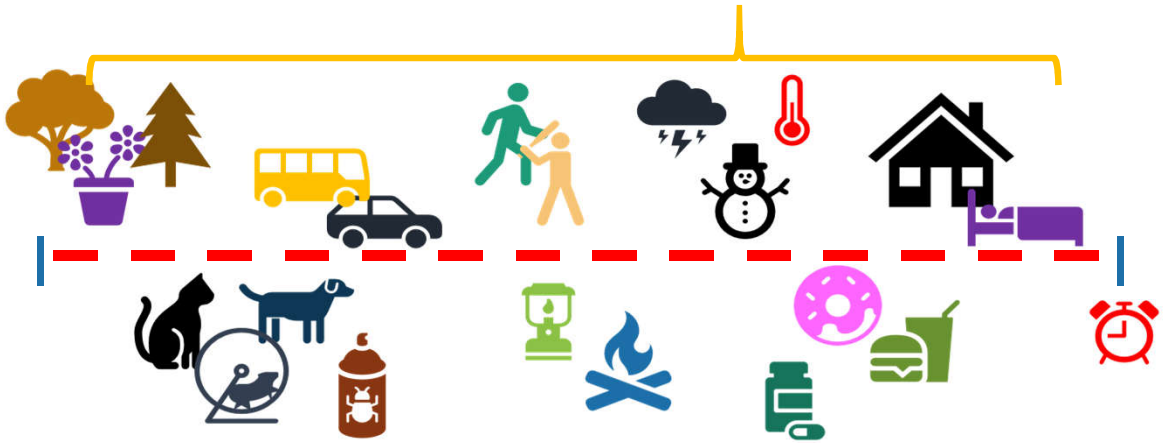
Accuracy

Within-person (over time, eg. Days)

Precision, drift

Precision, response time, performance across microenvironments, particle size distribution, particle composition and mobility

Within-day (within-person)



Other essential features and design recommendations…

Wearability/Usability

- User-centered design principles
- Desirable and comfortable to wear or carry, ‘real-life compatible’
- Flexible wear options (gender and age compatible)
- Safety + battery life + charging options
- ‘Smart’ calibration kits or options (zero)

Data processing/communication

- Ability to communicate *securely* and in real-time
- Capture QA/QC metadata + GPS + RH/Temp + wear compliance
  - On-board data storage
  - Ideally basic processing too
- Capacity to store data for 1hr+ when connection lost
- ‘Plug-and-play’ ability, advertise MAC address etc…

Thank You

- Questions? habre@usc.edu
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    - https://www.nibib.nih.gov/research-funding/prisms