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
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

- Self-reported symptoms, behaviors
- Automated, scheduled data collection
- Real-time environmental data
- Data Center
- Integrated, synchronized data views
- Electronic health record
- Healthcare provider feedback
- Data Dashboards
- Targeted material
- Tailored predictive models
- Real-time analysis
- Risk assessment and warnings
- SENSORS
  - Wireless sensor discovery and configuration
  - Automatic, secure data upload to the cloud
- Child and/or caregiver

About your asthma…

Healthcare provider feedback
Informatics Platform for Personal Air Pollution Monitoring in Children

Breathe Kit, Los Angeles PRISMS Center

**BREATHE Kit: Biomedical REAL-Time Health Evaluation**

- **AndroidWear Smartwatch + App**
- **AirBeam (PM2.5)**
- **Android Smartphone + Apps (Sensors and EMA)**
- **Inhaler**
- **Spirometer**

**Ecological Momentary Assessment (EMA) Surveys + mobile dashboards**

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

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

Graphs and tables showing data distribution and correlation.

### Overall


### By Microenvironment

- **Scenario**
  - Home, indoor: $A2_{PM} = 0.996 + 0.923*A1_{PM}$, $R^2: 0.591$
  - Lab, indoor: $A2_{PM} = 15.17 + 0.221*A1_{PM}$, $R^2: 0.028$
  - Office, outdoor: $A2_{PM} = 0.879 + 1.185*A1_{PM}$, $R^2: 0.897$
  - Outdoor, walk: $A2_{PM} = 1.986 + 0.905*A1_{PM}$, $R^2: 0.900$
  - Car, high AER: $A2_{PM} = 2.148 + 0.6705*A1_{PM}$, $R^2: 0.888$
  - Car, low AER: $A2_{PM} = 1.857 + 0.7067*A1_{PM}$, $R^2: 0.932$
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
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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