# Poster: myCityMeter: Helping Older Adults Manage the Environmental Risk Factors for Cognitive Impairment

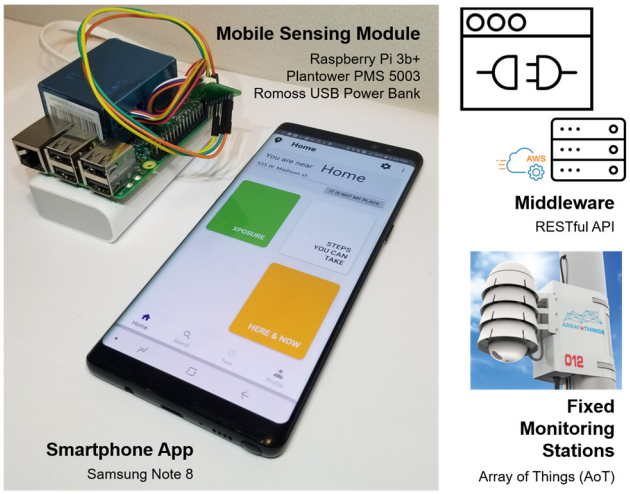


Figure 1. A system overview of myCityMeter.

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## Abstract

Recent epidemiological studies suggest that age-related cognitive decline—particularly, the stages between normal cognitive changes in aging and early dementia—is adversely affected by environmental exposures, such as long-term air pollution and traffic noise. Although monitoring outdoor air pollution is now commonplace, and smart home solutions for monitoring indoor air quality is becoming prevalent, ways that the elderly can record long-term environmental exposures and adopt healthy lifestyle changes are little explored. We present *myCityMeter*, a pollution exposure management tool for older adults and their caregivers. myCityMeter measures the pollutants shown to be associated with cognitive impairment in older adults: $PM_{2.5}$ and ambient noise. Using a set of neighborhood-level stationary and personal mobile sensors, myCityMeter helps users to monitor their environmental exposures, know potential exposures when planning activities, journal cognitive performances, and take day-to-day actions to avoid the environmental risk factors for early dementia.

## Author Keywords

Older adults; pollution exposure management; pollution monitoring; cognitive impairment; environmental sensing; pm2.5; noise; array of things.

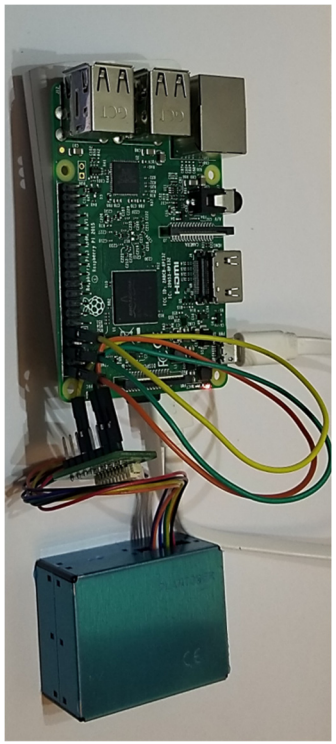

Figure 2: The mobile sensing module of myCityMeter is a wireless embedded sensing system with a computation and communication architecture based on the Raspberry Pi 3b+. It is a single board computer with a Bluetooth module, Wi-Fi, 1GB RAM, and 16GB storage. An off-the-shelf particle concentration sensor, Plantower PMS 5003, is mounted on the Pi along with a USB Power Bank (5V, 1A).


## ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.


## Introduction

Environmental exposures have long been known to cause chronic conditions, such as cardiovascular diseases. More recently, epidemiological studies have shown that long-term exposures to air pollution, particularly $PM_{2.5}$, and ambient noise are positively associated with mild-cognitive impairment (MCI) in older adults [8]. MCI describes the stages between normal cognitive changes due to aging and early dementia, e.g., amnestic type of MCI reflects the onset of Alzheimer disease. To manage the environmental risk factors (ERFs) for MCI, older adults need to monitor their personal exposures to $PM_{2.5}$ and noise.

Now monitoring *outdoor air pollution* has become commonplace, largely practiced via the government—using fixed [2] or mobile measurement stations [5]—and sometimes led by a community using participatory sensing [1, 6]. These systems are built for region-wide data collection and public awareness—not to monitor personal pollution exposures, because sensor readings are often at the macro level (e.g., there are four $PM_{2.5}$ governmental monitoring stations in Chicago).

On the other hand, *indoor air quality (IAQ) monitoring* technologies—that are increasingly becoming prevalent [4]—provides household-level pollutant data, such as volatile organic compounds (VOC) and $PM_{2.5}$ [3]. While IAQ monitors are portable, they are designed to be stationary (e.g., placed on a living room side table [4]) and thus, limited toward monitoring personal pollution exposures across outdoors and indoors.

In this work, we introduce *myCityMeter*—a system that helps older adults record their daily and yearly exposures to $PM_{2.5}$ and noise, monitor current level of pollutants, take actions to combat pollutants' adverse effects, and test cognitive functions for an early MCI diagnosis. Our system is composed of: (1) a mobile sensing module, (2) a middleware to access sensor readings near regional measurement stations, and (3) a smartphone application (Figure 1). The ERF data (i.e., $PM_{2.5}$ and noise) is gathered by using our mobile sensing module and the Array of Things (AoT) urban sensor network [2]. AoT has 91 functional sensing nodes installed in different localities of Chicago, 16 providing $PM_{2.5}$ readings, and 63 ambient noise level. Using a set of fixed and mobile sensors, myCityMeter records personal pollution exposures, thereby helping older adults to know and manage the environmental risk factors for mild cognitive impairment.

## myCityMeter: Pollution Exposure Management for Older Adults

myCityMeter is a pollution exposure management tool that monitors two pollutants, $PM_{2.5}$ and ambient noise, and records six exposure metrics: i) average $PM_{2.5}$ exposure over last 24 hours, ii) average $PM_{2.5}$ exposure over the last year, iii) average noise exposure over last 24 hours, iv) average noise exposure over the last year, v) average nighttime noise exposure, from 10 pm to 6 am, and vi) average nighttime noise exposure over the last year. These metrics reflect the findings from the latest epidemiological studies on environmental risk factors for cognitive impairment in older adults [8]. To aid an early MCI diagnosis, myCityMeter also provides users with the Self-administered Gerocognitive Examination (SAGE) [7]. SAGE is a brief cognitive assessment instrument; it is not auto-scored but made

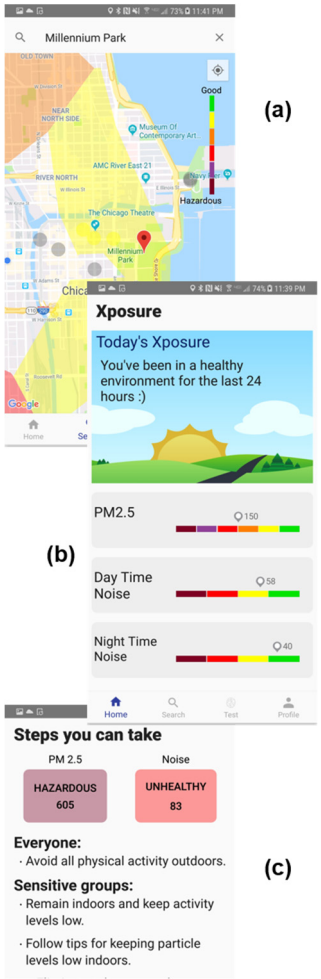


Figure 3. Screenshot of the phone application, lookup (a), monitoring exposure (b), and suggested actions (c).

available for scoring by a caregiver (family member or health provider). All user data are stored in a cloud server; user accounts are modeled as a collaboration between users and their caregivers. A user may add (or remove at any time) multiple caregivers to her account to allow them to monitor and score their cognitive performances and check their pollution exposures and last known location. Next, we discuss the three core components of myCityMeter, the sensing module, middleware, and smartphone application

## Mobile Sensing Module

myCityMeter's mobile sensing module functions in conjunction with its companion smartphone (or tablet). The sensing module is a wireless embedded sensing system with a computation and communication architecture based on the Raspberry Pi 3b+. It is a single board computer with a Bluetooth module, Wi-Fi, 1GB RAM, and 16GB storage. An off-the-shelf particle concentration sensor, Plantower PMS 5003, is mounted on the Pi, which uses a laser scattering principle to measure the number of airborne atmospheric particles whose diameter is less than a certain size in real-time. We programmed the sensor to measure $PM_{2.5}$; readings are transmitted per 5 s. The module is powered by a Romoss USB Power Bank (5V, 1A) and sensor data is transmitted to the Pi via SPI using the board's GPIO (Figure 2). The module is 3.2 x 2.2 x 1.7 inches and weighs about 100 gm and can be attached to a cane, belt, or tote. Pi sends the $PM_{2.5}$ readings directly to a cloud server when a Wi-Fi connection is available; or else readings are sent to the phone via a Bluetooth connection, and then the phone transmits the data to the server via LTE. If both Wi-Fi and Bluetooth are unavailable, readings are stored locally in the Pi. Each reading is geotagged (using the phone's GPS) and timestamped. The phone also records the ambient noise level and transforms the noise signal with A-weighting [dB(A)] before storing in the server. Our prototype currently works with an Android OS.

## Middleware: Using Other Monitoring Stations

A core challenge in using mobile pollution monitoring sensors is a lack of measurement accuracy. They are suboptimal compared with much expensive and professionally maintained fixed pollution monitoring stations. However, fixed monitoring stations only provide macro-level readings. To complement our mobile pollution monitoring system, we built a middleware to access $PM_{2.5}$ and noise data from fixed monitoring stations. It gathers data from Chicago's (US) Array of Things (AoT) urban sensing nodes [2] and communicates with the phone client app using a RESTful API. We decided to use neighborhood-level AoT data instead of US EPA data (Environmental Protection Agency) as AoT provides much detailed information (16 $PM_{2.5}$ AoT nodes vs. 4 EPA nodes) and noise data.

The middleware of myCityMeter is hosted in an AWS cloud; it interacts with the AoT server to get $PM_{2.5}$ and noise data. Meanwhile, the client app in the phone records users' current location (if allowed) and sends it to the middleware. If a user is within 50 feet of an AoT node, a weighted average of the AoT readings—$G(x, y)$—is used along with the local readings to calculate the pollution exposure. The weights ($w_i$) are computed by first creating a Voronoi tessellation with $n$ AoT nodes $(x_i, y_i)$ and then computing a natural neighbor interpolation with the user's current location $(x, y)$:

$$G(x,y) = \sum_{i=1}^{n} w_i f(x_i, y_i)$$

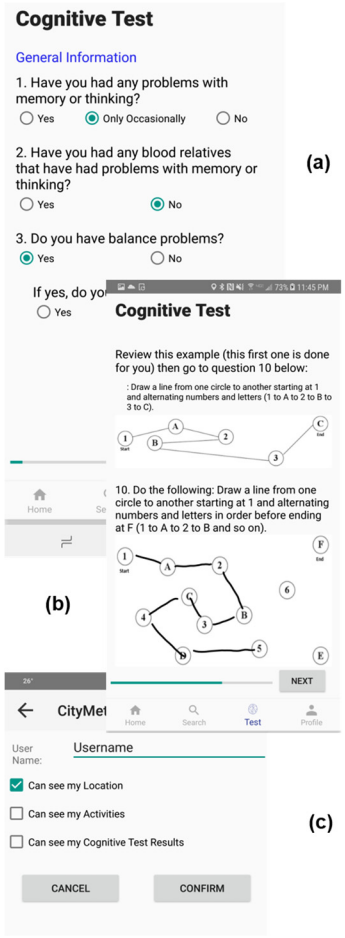


Figure 4. Screenshots of the SAGE cognitive test for diagnosing MCI (a, b) and giving caregivers monitoring permissions (c).

## Smartphone Application

The phone app allows users to look up current pollution and their daily and yearly pollution exposures (Figures 3a and 3b). It suggests actions that users can take to avoid the adverse effects of pollutants (Figure 3c) and the SAGE cognitive test (Figures 4a and 4b). Users can further add their caregivers and provide different permissions (Figure 4c), such as to score and monitor their cognitive tests or access their current location. Accounts are not required to simply look up pollution levels, but only when logging pollution exposure metrics and cognitive test scores. Although targeted for older adults, the system can also be used by others.

## Conclusion and Future Work

It is estimated that by 2020, 42.7–48.1 million people worldwide will suffer from dementia. MCI, a precursor to dementia, is associated with long-term exposures to $PM_{2.5}$ and ambient noise [8]. To record users' personal exposure to pollutants like $PM_{2.5}$ and ambient noise, in this work, we presented the design and implementation of myCityMeter, a pollution exposure management tool. myCityMeter contributes to the UbiComp literature on environmental pollution monitoring by introducing a hybrid approach toward sensing personal pollution exposure—leveraging a suboptimal mobile module and an array of city-wide high-precision fixed stations [2].

Next, we plan to refine our mobile sensing module by building a customized printed circuit board and use the recent advancements in airborne particulate matter sensing, such as their inch-scale size. We are also integrating other stationary sensing sources in our middleware, such as the national monitoring stations, and planning to use Bayesian methods to compute personal exposures. Finally, we will conduct longitudinal user studies to understand the use of myCityMeter by older adults and their caregivers.

## References


1. Ambiciti. Environmental awareness for all. Retrieved July 8, 2018 from http://ambiciti.io/
2. Array of Things. Retrieved July 8, 2018 from https://arrayofthings.github.io/
3. Biyi Fang, Qiumin Xu, et al. 2016. AirSense: an intelligent home-based sensing system for indoor air quality analytics. In *Proc. UbiComp '16,* 109–119. https://dx.doi.org/10.1145/2971648.2971720
4. Sunyoung Kim and Eric Paulos. 2009. inAir: measuring and visualizing indoor air quality. In *Proc. UbiComp '09*, 81–84. https://dx.doi.org/10.1145/1620545.1620557
5. Yongsung Kim, Julien Eberle, Riikka Hanninen, Erol Can Un, et al. 2013. Mobile observatory: an exploratory study of mobile air quality monitoring application. In *Proc. UbiComp '13 Adjunct*, 733–736. https://dx.doi.org/10.1145/2494091.2495997
6. Nima Nikzad, Nakul Verma, et al. 2012. CitiSense: improving geospatial environmental assessment of air quality using a wireless personal exposure monitoring system. In *Proc. WH '12,* 11:1–8. https://dx.doi.org/10.1145/2448096.2448107
7. Douglas W. Scharre, Shu-Ing Chang, et al. 2010. Self-administered Gerocognitive Examination (SAGE): a brief cognitive assessment instrument for mild cognitive impairment (MCI) and early dementia. *Alzheimer Disease & Associated Disorders*, *24*, 1: 64–71.
8. Lilian Tzivian, Martha Dlugaj, Angela Winkler, et al. 2016. Long-term air pollution and traffic noise exposures and mild cognitive impairment in older adults: a cross-sectional analysis of the Heinz Nixdorf recall study. *Environmental health perspectives*, *124*, 9:1361.