

My Air, My Health Challenge Solution

Solution submitted by:

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Category 1

1) Production of a functional prototype

a) Provide Proof of Concept Study evidence that the prototype is viable as wearable/portable device(s):

i) Minimally invasive/intrusive

Our prototype solution for the My Air, My Health Challenge employs three pieces of equipment to record, display, and share the air quality and physiological data collected by volunteer participants: an Android smartphone running the AirCasting app, an AirGo air monitor, and a Zephyr BioHarness 3 physiological monitor.

- The Android smartphone: a Kyocera Event, measures 4.53" in height x 2.41" in width x 0.46" in depth, weighs 4.1 oz. and is normally carried in a pocket or bag.
- The AirGo measures 4.5" in height x 2.75" in width x 1.4" in depth, weighs 5.75 oz. and is fastened to an Arkon XXL armband weighing 2.9 oz. that can be worn on the bicep or strapped to a bag. The AirGo is powered by an external battery, an Anker Astro Mini, which measures 3.5" in height x 0.91 in diameter and weighs 2.7 oz. It is also attached to the armband.
- At its maximum the BioHarness is 1.85" in diameter x .5" in depth and of varying length. The BioHarness weighs 3.1 oz., is worn around the circumference of chest, and is held in place by a shoulder strap.

Because of their small size, light weight and the manner in which they are worn/carried, each of these devices is minimally invasive/intrusive. Feedback from participant volunteers indicated that the BioHarness caused some discomfort after prolonged use due to the fact that it had to be worn against the skin and needed to be moist. Chafing and itchiness were the most common BioHarness related complaints. Participant volunteers reported that the Android smartphone and AirGo were unobtrusive and easy to wear though the white noise generated by the AirGo fan registered as a minor annoyance at times. The wearable nature of the prototype and its minimally invasive character are demonstrated in the provided video, available online at <http://youtu.be/dRnS0sf3D2A>.

ii) Low maintenance

In addition to being minimally invasive/intrusive the devices are also low maintenance, requiring only that they be charged at regular intervals. In testing, we found that the battery life of each of the devices was approximately 5-8 hrs for the smartphone, 5-6 hrs for the AirGo, and up to 20 hrs for the BioHarness.

b) Demonstrate robustness of device(s)

i) Device(s) stand up to everyday use

Each of the three devices stood up well to everyday use. The smartphone and BioHarness are both commercially available products that have seen extensive product testing prior to release to ensure they can withstand the rigors of consumer use. Our successful use of these devices confirms that they are indeed robust. The AirGo enclosure, printed on a 3D printer, is also very durable having been constructed of flexible plastic. The durability of the electronics inside the AirGo are less certain at this early stage of development. All the components performed well during use but the limited time frame of the Challenge and our pilot community health study did not allow for testing the devices to failure to assess expected lifespan, though we did have one of the six electrochemical CO sensors immediately fail within the first few hours of operation.

ii) Data consistently sent and received as intended

The data from the AirGo and BioHarness is transmitted to the smartphone approximately once per second via Bluetooth. At the end of a recording session, the data are transmitted to a web server for storage and, if the AirCaster elects to make their session public, display. The session data was also Emailed from the smartphone as a CSV file for analysis in Excel.

The data were found to be consistently sent and received as intended. However, there were exceptions, which were confined to the occasional failure of the AirCasting app and AirGo or the AirCasting app and BioHarness to maintain an active Bluetooth connection. Testing did not identify any one root cause that could be remedied to address these occasional Bluetooth communication failures, though in the case of the BioHarness, nearly all the Bluetooth communication failures were experienced while connected to one specific Android smartphone make and model. Additional testing indicates that this problem does not manifest itself on most Android devices, which are able to maintain a consistent connection with the BioHarness for the duration of a session.

Data transmission was occasionally interrupted due to the smartphone or app crashing. These crashes usually occurred after two or more hours of data had been recorded during a single session. To minimize the data loss associated with these crashes, we implemented incremental session saving, wherein data are backed up locally and the AirCaster is then provided an opportunity to save the session data post-crash. These crashes are most likely the result of mapping tens of thousands of points and can be prevented in the future by optimizing data storage, retrieval, and display and in the present by accessing the AirCasting app settings and disabling the mapping feature.

c) Demonstrate usability of interface design

i) Understandable to users and easy to learn

ii) Generally leads to correct use of device(s) and apps/programs

Android device owners can download the AirCasting app via the Google Play Store app, <http://bit.ly/AirCastingAndroid>.

The AirCasting app was designed to make recording, mapping, and sharing health and environmental data as simple and straightforward as possible for the user. The primary interface

for the AirCasting app provides four ways to view the data: the “Sensors Dashboard”, the “Route Map”, the “CrowdMap”, and the “Graph”. Toggle between views by tapping the triangular buttons located on the left and right sides of the screen. If the buttons are not displayed, the screen can be tapped once to make them appear and tapped again to make them disappear.

The “Sensors Dashboard” displays the measurements from all the user’s sensor streams simultaneously. Tapping the record buttons next to each sensor stream will toggle recording off/on. Tapping the eye icon selects that sensor stream for viewing on the Route Map, CrowdMap, and Graph.

The “Route Map” displays the user’s current position as a colored dot with a white outline; dots without an outline are past measurements. A dot’s color corresponds to the measurements intensity at a location. Refer to the “Heat Legend ” (the colored bar at the top of the screen) to identify the intensity range for a measurement. For example, a yellow dot corresponds to a sound level measurement between 61 and 70 decibels.

The “CrowdMap” displays AirCasting data from all contributors. Each square’s color corresponds to the average intensity of all the measurements recorded in that area. Refer to the “Heat Legend” to identify the intensity range for a square. For example, an orange square corresponds to an average sound level between 71 and 80 decibels. If no colors are displayed, there are no data in that area.

The “Graph” displays a user’s measurements over time. Zoom in and out for more or less detail, swipe to pan through the data.

To adjust the relationship between sensor measurements and display colors, tap the “Heat Legend”: the colored bar at the top of the screen. To toggle between sensor streams tap the “Avg”, “Now”, “Peak” circles at the top of the screen.

To access the more detailed instructions provided to the pilot community health study volunteer participants see “Appendix A: AirCasting How to Guide for My Air, My Health Participant Volunteers”.

Despite the simple and straightforward nature of the AirCasting app user interface, managing three devices using the current configuration is somewhat more complicated. Running the AirGo for an hour prior to recording (in order to stabilize the electrochemical CO sensor), putting on the AirGo and BioHarness, connecting the AirGo and BioHarness to the AirCasting app via Bluetooth, occasionally checking to make sure the Bluetooth connection is still active while recording a session, confirming the validity of the BioHarness measurements and adjusting or re-wetting the strap if necessary, making notes and taking pictures, saving and emailing sessions, and charging all the devices after each session is not a simple affair. Feedback from participant volunteers indicated that they managed to do all these things and enjoyed being part of the pilot, but the experience of managing the devices using the present configuration was not yet seamless or effortlessly integrated into their daily routines. Future instrument developments will seek to address and minimize these remaining procedural barriers to use.

Deliverables 1

1. Deliver the actual prototype (not finished product, but it should work) – video is acceptable
See video, available online at <http://youtu.be/dRnS0sf3D2A>.

2. Show how device prototype is wearable by diagram and simple instructions. It should be obvious to the Seeker how to wear it from instructions. Video is acceptable.

See video, available online at <http://youtu.be/dRnS0sf3D2A>. Also see “Appendix A: AirCasting How to Guide for My Air, My Health Participant Volunteers”.

3. Robustness might be built in (like in a cell phone), but it should be clear that it will last and not need continual maintenance. You do not necessarily need to generate the evidence, but you do need to provide some. Video is acceptable.

See video, available online at <http://youtu.be/dRnS0sf3D2A>.

4. Provide information showing data transfer is consistent from previous tests and/or data.

See video, available online at <http://youtu.be/dRnS0sf3D2A>. Also see response, “Deliverables 3.1.”

5. The steps to setup and operate the prototype should be spelled out in simple instructions. The user should be able to figure it out from your instructions.

See video, available online at <http://youtu.be/dRnS0sf3D2A>. Also see “Appendix A: AirCasting How to Guide for My Air, My Health Participant Volunteers”.

Category 2

2) Demonstration of Sensor Performance in the Field Provide Proof of Concept Study evidence that sensors successfully detect and quantify pollutants and their effects, and provide physiologically relevant air quality and associated health data.

a) Pollutant sensor accuracy / precision / sensitivity / specificity, robustness, and sampling frequency

The AirGo air monitor measures: carbon monoxide using an Alphasense CO-B4 sensor, particulate matter using a Samyoung DSM501A sensor, and temperature and relative humidity using a Sensirion SHT15 sensor. Sensor data is processed via a custom printed circuit board. The board schematics are open source and can be downloaded from GitHub, <http://bit.ly/11XVfX3>. All of these components are housed inside an enclosure with a fan that pulls air over the sensors. The files for 3D printing the enclosure are open source and available for download via Shapeways, <http://bit.ly/11VYMqh>.

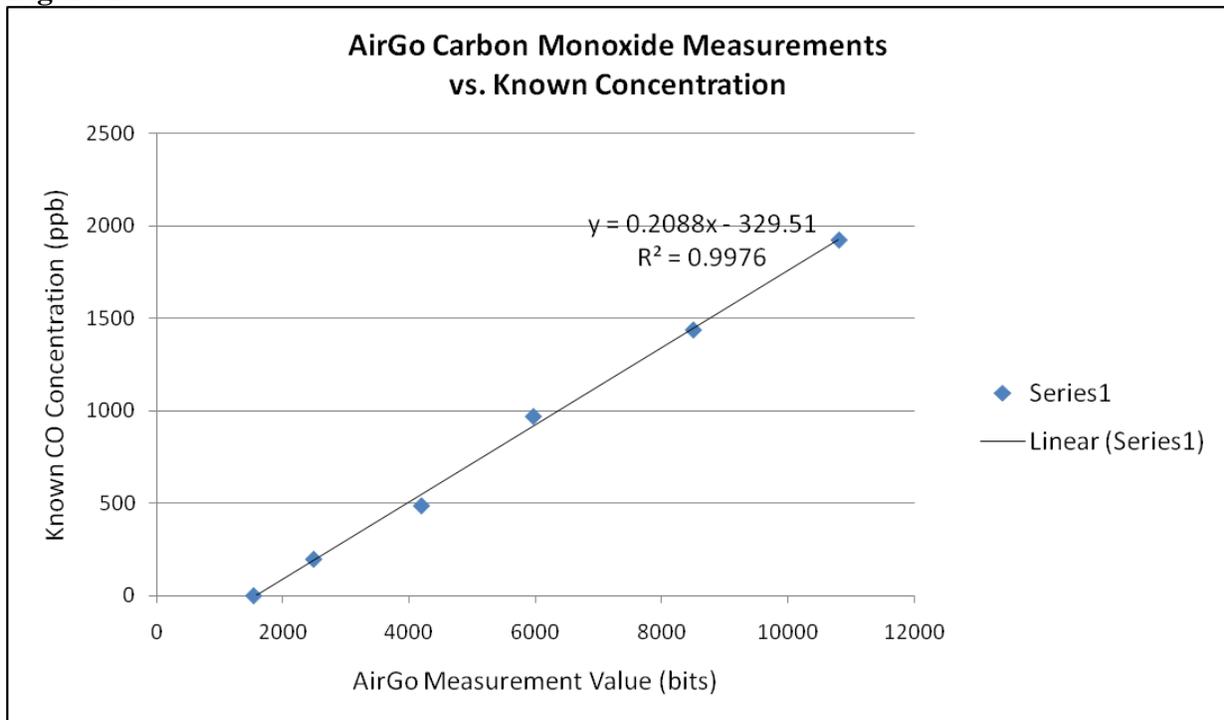
Performance data for the Alphasense CO-B4, taken from the manufacturers data sheet (available online, <http://bit.ly/CO-B4>), is provided in Figure 1.

Figure 1: Performance Data for the Alphasense CO-B4

Sensitivity	nA/ppm in 2ppm CO	500 to 750
Response time	t ₉₀ (s) from zero to 10ppm CO	< 25
Zero current	nA in zero air at 20°C	-30 to -120
Noise*	RMS noise (ppb equivalent)	< 10
Limit of detection*	ppb equivalent	< 5
Range	ppm limit of performance warranty	50
Linearity	ppm CO error at full scale, linear at zero, 15ppm CO	< ± 1
Overgas limit	maximum ppm for stable response to gas pulse	100

Our own performance tests of the CO-B4 revealed that the sensor provides outputs well correlated with known CO gas concentrations within a range that is typical of ambient levels found in urban areas of the US. On May 2, 2013, a student of Dr. Thurston’s visited the New York State Department of Environmental Conservation (NYSDEC) air monitoring station at Queens College in Queens, NY. The AirGo unit was placed in a plastic bag filled with known CO concentrations from a state-owned CO calibration unit. The comparisons of the AirGo output to the NYSDEC calibrator “known concentrations” (ranging from 0 to 2 ppm) are shown in Figure 2. As is illustrated in the figure, the correlation is nearly perfect (R² = 0.99), indicating that the AirGO unit is sensing CO very precisely. With this calibration information incorporated into the software, the AirGo will give accurate measurements for CO at ambient levels.

Figure 2



Performance data for the Samyoung DSM501A, taken from the manufacturers data sheet (available online, <http://bit.ly/DSM501A>), is also provided below.

Figure 3: Electrical Characteristics for the Samyoung DSM501A

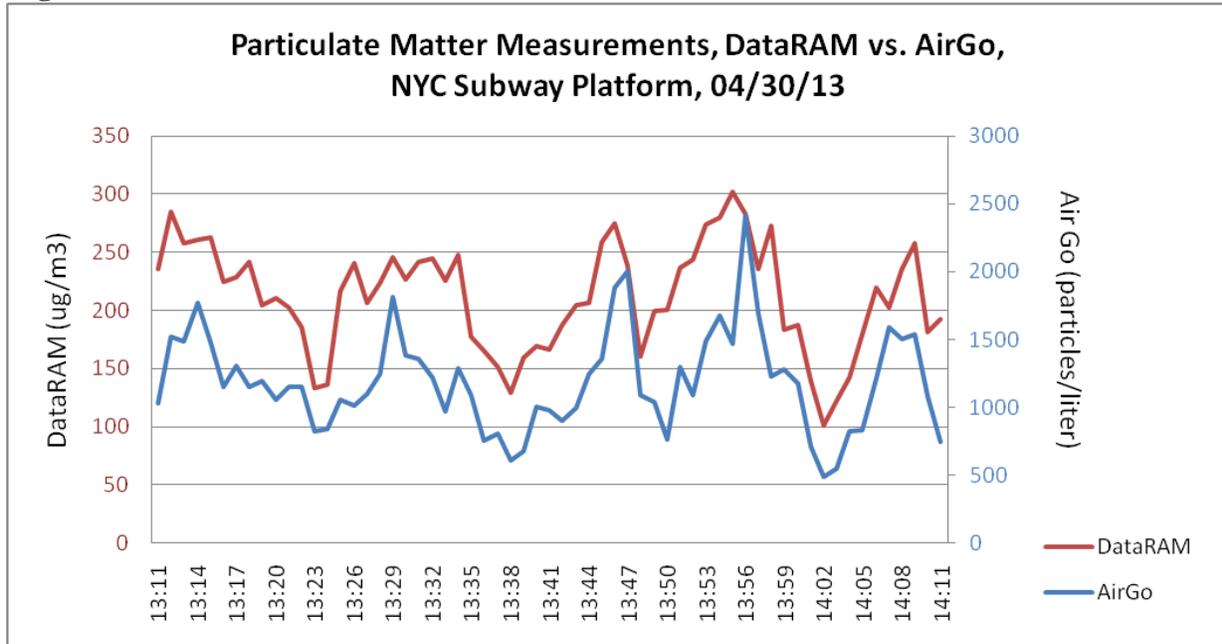
4 - 1. Supply voltage	: DC5V±10%
4 - 2. Power consumption	: 90mA
4 - 3. Operating temperature range	: -10~ +65°C
4 - 4. Operating humidity range	: 95%RH or less (without dew condensation)
4 - 5. Recommend storage condition	: -20~ +80°C
4 - 6. Dimension	: W59 * H45 * D20 (mm)
4 - 7. Detectable particle size	: approx. 1µm (minimum)
4 - 8. Detectable range of concentration	: 0 ~ 1.4mg/m ³
4- 9. Output signal	: PWM (pulse width modulation)
4 -10. Time for stabilization	: 1 minute after power turned on
4-11. Sensor characteristics	: To be maintained in between the upper limit and lower limit of the standard dust sensor unit

Our own field and performance tests of the DSM501A revealed that in comparison with an industry standard particle counter, the Hach HHPC-6, the dust sensor responds most strongly to particles of approximately 2 microns in diameter. Because our real-time monitors measure particle counts and sizes rather than mass, we calibrate and convert the sensor to output in particles per liter or cubic foot. The datasheet provides a plot of sensor duty cycle versus particle concentration, but we find that readings are sparse and inconsistent enough that this is a very ineffective conversion. Instead, we have implemented a stepwise function to constantly update a running estimate of particle concentration every time a particle is detected. This effectively gives more weight to particle detection rather than absence, as a period of particle detection contains more information than no detection at all. This method has been used successfully on both the DSM501A and the Shinyei PPD42NS, and should be applicable to other sensors as well. Adjustment of the algorithm is ongoing and will be even more effective in the coming months as we gather additional calibration data.

On April 30, 2013, a graduate student of Dr. Thurston's went to the 9th Street subway station in Manhattan, near NYU's Washington Square Park campus, to compare the 1-minute average particulate matter concentrations recorded by the inexpensive AirGO with the concentrations recorded by a Thermo MIE pDR-1000 DataRam continuous PM_{2.5} sampler that costs over \$4000 (Thermo Electron Corporation, Franklin, MA). This location was selected because it provides a population exposure that varies over time (as trains pass by), allowing a wide range of exposures to be compared over a relatively short sampling period. As shown in the figure below, comparisons of these two instruments during ambient sampling yielded well correlated outputs over time, following each other up and down in concentration as the subways passed by the

station. A regression of the two records yielded the calibration line: $y = 0.0984x + 94.656x$ ($R^2 = 0.61643$) where $y = \mu\text{g}/\text{m}^3 \text{PM}_{2.5}$ from the DataRAM, and $x = \text{particles}/\text{liter}$ from the AirGo. This regression indicates that with the application of a conversion equation, such as the one developed for this case, the AirGo is capable of giving similar output to the far more expensive DataRAM unit at real-world exposure conditions.

Figure 4



It should be noted that the DSM501A is susceptible to light interference if not integrated in a manner that minimizes this effect. In particular, bright sunlight, with its strong infrared component, appears to interfere most with the measurements. The present AirGo enclosure design was not entirely successful at eliminating light interference in such bright daytime settings. Future development of the AirGo will aim to fully eliminate such light interference.

Performance data for the Sensirion SHT15, taken from the manufacturers data sheet (available online, <http://bit.ly/SHT15>), is provided below.

Figure 5: Performance Data for the Sensirion SHT15

Relative Humidity						Temperature					
Parameter	Condition	min	typ	max	Units	Parameter	Condition	min	typ	max	Units
Resolution ¹		0.4	0.05	0.05	%RH	Resolution ¹		0.04	0.01	0.01	°C
		8	12	12	bit			12	14	14	bit
Accuracy ² SHT10	typical		±4.5		%RH	Accuracy ² SHT10	typical		±0.5		°C
	maximal	see Figure 2						maximal	see Figure 3		
Accuracy ² SHT11	typical		±3.0		%RH	Accuracy ² SHT11	typical		±0.4		°C
	maximal	see Figure 2						maximal	see Figure 3		
Accuracy ² SHT15	typical		±2.0		%RH	Accuracy ² SHT15	typical		±0.3		°C
	maximal	see Figure 2						maximal	see Figure 3		
Repeatability			±0.1		%RH	Repeatability			±0.1		°C
Replacement		fully interchangeable				Replacement		fully interchangeable			
Hysteresis			±1		%RH	Operating Range		-40		123.8	°C
Nonlinearity	raw data		±3		%RH			-40		254.9	°F
	linearized		<<1		%RH	Response Time ⁶ τ (63%)		5		30	s
Response time ³	τ (63%)		8		s	Long term drift			< 0.04		°C/yr
Operating Range		0		100	%RH						
Long term drift ⁴	normal		< 0.5		%RH/yr						

Temperature and relative humidity measurements were recorded in order to allow for adjustment and recalibration of the PM and CO measurements, both of which may be affected by changes in the ambient environment. While we have yet to collect sufficient data to implement reliable temperature and humidity corrections for the sensor measurements, future iterations will do so.

b) Physiological sensor accuracy / precision / sensitivity / specificity, robustness, and sampling frequency

We captured and recorded the following parameters from the Zephyr BioHarness 3 in one second intervals: activity level, breathing rate, core temperature, heart rate, heart rate variability, peak acceleration, and R to R. Because the BioHarness is a commercial product it is reasonable to assume, at this point, that the manufacturers testing was rigorous and the measurements can be trusted within the confidence ranges specified in the data sheet. Future work will confirm this with direct comparisons to hospital grade units. Performance data for the BioHarness, taken from the manufacturers data sheet (available online, <http://bit.ly/BH-3>), are provided below.

Figure 6: Specifications for the Zephyr BioHarness 3

Heart Rate Accuracy for defined activity levels: based on USARIEM* guidelines					
Accuracy (bpm)	Activity Level	VMU	USARIEM % of time	Zephyr % of time	Max Deviation (bpm)
±1	Laboratory – ECG simulator		100	99	1
±2	Low activity (static)	< 0.2	99	99	5
±3	Moderate activity (walk/jog)	< 0.8	95	96	5
±3	High activity (run)	> 0.8	90	96	10

Breathing Rate Accuracy for defined conditions: based on USARIEM* guidelines					
Accuracy (Bpm)	Condition (average every 15 seconds)	VMU	USARIEM % of time	Zephyr % of time	Max Deviation (bpm)
±2	Laboratory – breathing emulator		100		2
±3	Low activity (static)	< 0.2	95	75	5
±3	Moderate activity (walk/jog)	< 0.8	95	65	5
±5	High activity (run)	> 0.8	90	75	12
±5	Talking & breathing rate in range 6 – 25 bpm		100		

Deliverables 2

1. Deliver proof the sensor measures what you say it measures including precision and accuracy of both the pollutant and physiological data as described above.

See response, “Category 2.a.”

2. Data needs to be generated and provided. Show prototype use in the field. Video is acceptable.

See “AirCasting Example Session”, online at <http://bit.ly/ACexample>. Also see video, available online at <http://youtu.be/dRnS0sf3D2A>.

Category 3

3) Demonstration of data handling, processing and analysis Provide Proof of Concept study evidence that data processing software and algorithms are capable of analyzing connections between, and patterns in, air/health measurements, providing physiologically relevant and usable output.

a) Viability of data processing algorithms

See below. Also see response, “Deliverables 3.2”

b) Viability of data reporting

See below. Also see response, “Deliverables 3.1.”

c) Understandability of presentation/interpretations for intended users

See below. Also see video, available online at <http://youtu.be/dRnS0sf3D2A>.

Data Handling, Processing and Analysis

This section of the report illustrates how our solution can be used to collect, store, and analyze data to conduct research on the association between air quality data (carbon monoxide (CO) and particulate matter (PM) concentrations) and health data (heart rate variability, HRV). The data in this section of the report was collected using the AirCasting app and the hardware shown in Figure 7. On the left of the figure is the Zephyr BioHarness which collects data on HRV and other variables of interest. In the middle of the image is the AirGo device which includes sensors to measure the concentration of CO and PM. And on the right is a smartphone running the Android operating system. It allows the user to run the AirCasting app which collects the data from the other two devices and stores, displays, and shares it depending on user preferences.

Figure 7. Equipment Used During an AirCasting Session



The data presented in this section of the report were collected by one of the team members over a period of approximately one hour in the Washington Heights neighborhood of Manhattan on May 5th, 2013. During this period there were technical problems maintaining a connection between the BioHarness and the AirCasting app, hence the BioHarness data are incomplete. Since this section is only meant to illustrate how the devices are used to collect and analyze data and not to present original research results the team decided to include it here. The problem with maintaining a connection to the BioHarness is specific to the make and model of the Android smartphone used. Additional testing indicates that this problem does not manifest itself on most Android devices, which are able to maintain a consistent connection with the BioHarness for the duration of a session.

As mentioned earlier, the primary health variable of interest is heart rate variability. According to information provided by Zephyr, HRV measures the time interval between heart beats or cardio-intervals, which is measured by the variation in the beat-to-beat interval (Source: <http://www.zephyr-technology.com/zephyr-labs/>). A number of studies have shown an inverse association between air pollution concentrations and HRV (Dales 2004; Park 2005; Ayres 2006). But air pollution is not the only factor that can influence HRV. Another advantage of using a smart phone as part of this solution is that it allows users to collect data on other variables that could potentially confound the relationship between air pollution and HRV. One of these variables is noise. A recent study found that high levels of noise can also affect HRV (Kraus et al 2013). The AirCasting application also records sound levels in dB using the smartphone microphone, so as part of this solution we can control for this variable. Another advantage of using a smartphone is that it allows users to annotate their session using written or audio notes and also to photograph their surroundings, which could provide clues about sudden or unusual changes in the data collected.

For example, in the AirCasting session detailed herein the user encountered very different urban environments. Figure 8 shows a street in Washington Heights with little traffic that is typical of streets in the neighborhood with an east-west orientation. Figure 9 shows Broadway, a much wider road with heavier traffic. Figure 10 shows an important infrastructure facility in the neighborhood, the George Washington Bridge Bus Station. Such a facility could easily explain sudden changes in noise and pollution concentrations. HRV is also related to physical exercise (Bailón et al 2010; Bailón et al 2011). Figure 11 shows a steep staircase which is something that could account for a sudden change in HRV and could give researchers a clue about such changes. Finally, a park such as Fort Tryon Park, shown in Figure 12, could also be associated with much lower pollution concentrations and noise and could also impact HRV.

Figure 8. 164th Street



Figure 9. Broadway



Figure 10. GW Bridge Bus Station



Figure 11. Staircase in Washington Heights



Figure 12. Fort Tryon Park



Data Analysis

Table 1 summarizes the data collected during the AirCasting session recorded on May 5th, 2013 in the Washington Heights neighborhood of Manhattan. As mentioned in our response to “Category 2.b.”, the BioHarness collects data on HRV (milliseconds) as well as other related variables such as R to R (milliseconds), and heart rate (beats per minute). The AirGo measures PM (thousands of particles per cubic foot) and CO (ppb). The smart phone records sound levels (dB). In addition, a number of physiological measures recorded by the BioHarness can provide researchers and users with an indication of physical exertion and exercise intensity. The BioHarness measures breathing rate (breaths per minute), peak acceleration (standard gravity), activity level (Vector Magnitude Units), and estimated core body temperature. As Table 1 shows, the sensor streams are reported using slightly different time intervals of approximately one second, so the number of observations differs for the variables in these example data. In addition, as mentioned earlier, during this preliminary AirCasting session the BioHarness got disconnected several times, so the HRV and related variables show a significantly lower number of observations than the variables measured using the AirGo.

Table 1. Descriptive Statistics for Data Collected as Part of an AirCasting Session in Washington Heights, Manhattan

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
HRV (BioHarness)	153	9.00	26.00	16.8954	5.74704
R to R (BioHarness)	281	287.00	1040.00	548.1708	58.40560
Breaths/Min (BioHarness)	153	24.20	41.30	29.9359	6.27348
HR_bpm (BioHarness)	153	98.00	117.00	110.4444	5.14256
PM (AirGo)	1376	5.00	1305.00	789.8052	406.05600
CO_ppb (AirGo)	1377	.00	36.00	18.9267	5.44393
Sound_dB (phone microphone)	1443	41.77	69.24	51.2555	4.34812
PeakAcceleration (BioHarness)	153	19.00	106.00	64.1830	11.22640
Valid N (listwise)	153				

The data included in Table 1 provide an indication of the level of variation possible. For example, there is a significant amount of variation in the PM data. The lowest values were recorded at the end of the session when the user was in Fort Tryon Park, away from traffic. HRV values did not vary very significantly and the values seem to have decreased steadily as the session progressed. Figure 13 shows the PM data collected during the session and Figure 14 shows the CO data.

Figure 13.

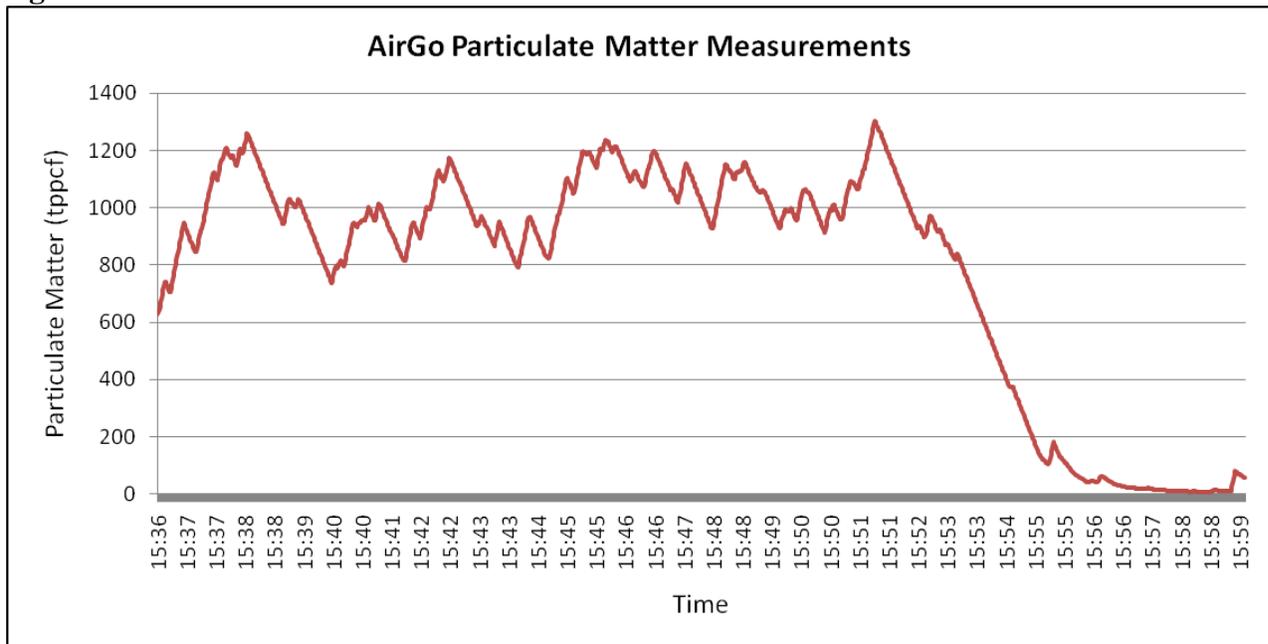
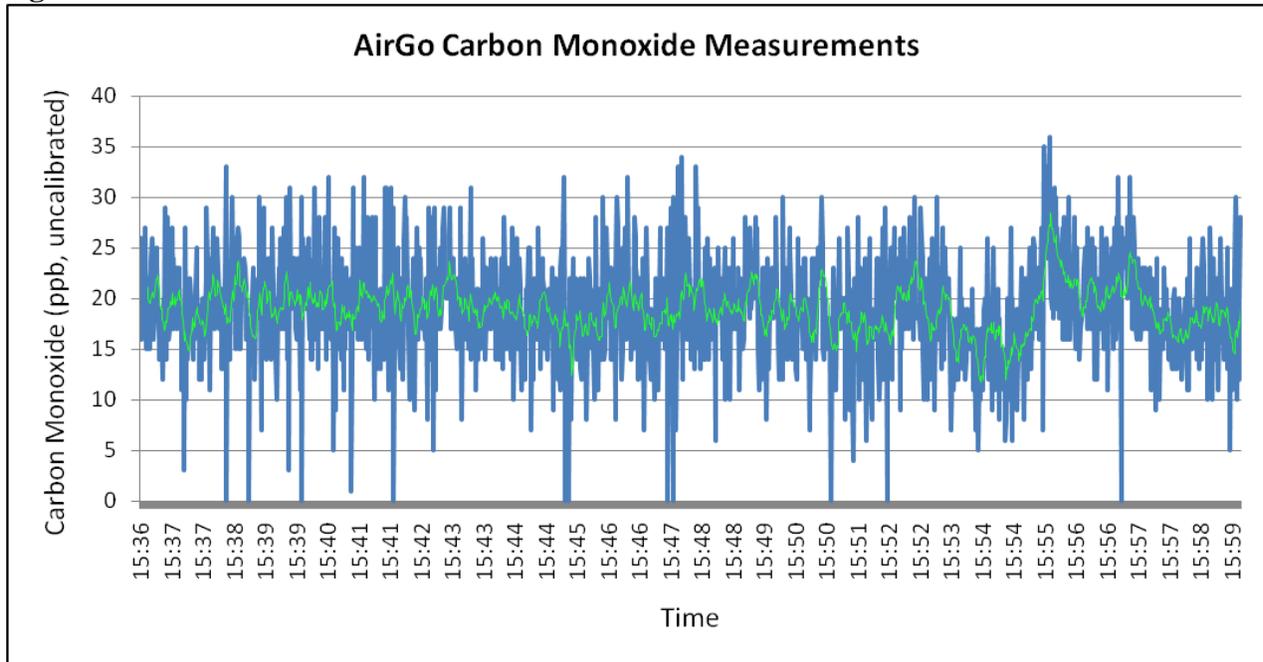


Figure 14.



In order to address the discrepancies caused by the time periods during which the BioHarness was disconnected, a sample of data was selected to illustrate what the actual data looks like and how they could be used. A total of 68 observations for HRV were selected and using the time stamp associated with the data a table was constructed with the nearest values for R to R, CO, PM, sound level and peak acceleration using the time domain. This subset of the data is shown in Table 2.

Table 2. Subset of the Data for Selected Variables

Timestamp	HRV (ms)	RtoR (ms)	CO (ppb, uncalibrated)	PM (tppcf)	Sound level (dB)	Peak Acceleration (vmu)
2013-05-05T15:38:47.662-0400	16	525	16	1094	46.71	54
2013-05-05T15:38:48.669-0400	16	526	15	1087	45.00	53
2013-05-05T15:38:49.669-0400	16	533	16	1080	44.48	55
2013-05-05T15:38:50.671-0400	15	530	20	1073	58.84	60
2013-05-05T15:38:51.666-0400	15	526	23	1066	47.88	55
2013-05-05T15:38:52.670-0400	15	525	22	1059	45.82	62
2013-05-05T15:38:53.671-0400	15	524	12	1052	45.58	62
2013-05-05T15:38:54.666-0400	14	528	18	1045	45.64	66
2013-05-05T15:38:55.670-0400	14	520	20	1038	45.99	71
2013-05-05T15:38:56.671-0400	14	522	20	1031	49.89	56
2013-05-05T15:38:57.666-0400	14	526	22	1024	49.69	55
2013-05-05T15:38:58.671-0400	14	529	18	1017	48.52	53
2013-05-05T15:38:59.671-0400	14	532	30	1010	52.46	57
2013-05-05T15:39:00.667-0400	13	527	20	1002	49.29	61

2013-05-05T15:39:01.671-0400	13	526	7	995	48.29	57
2013-05-05T15:39:02.671-0400	13	1040	16	988	46.35	60
2013-05-05T15:39:03.671-0400	13	522	28	981	47.19	63
2013-05-05T15:39:04.673-0400	13	518	29	974	47.35	61
2013-05-05T15:39:05.674-0400	13	519	23	967	48.41	61
2013-05-05T15:39:06.674-0400	13	520	24	960	48.54	59
2013-05-05T15:39:07.674-0400	12	522	16	953	49.43	57
2013-05-05T15:39:08.673-0400	12	522	14	946	50.25	60
2013-05-05T15:39:09.675-0400	12	515	18	944	52.46	61
2013-05-05T15:39:10.675-0400	12	519	24	951	46.97	69
2013-05-05T15:39:11.674-0400	12	517	16	965	47.42	59
2013-05-05T15:39:12.675-0400	11	519	15	980	44.64	60
2013-05-05T15:39:13.676-0400	11	518	17	994	43.59	67
2013-05-05T15:39:14.676-0400	11	519	14	1008	45.39	61
2013-05-05T15:39:15.677-0400	11	522	27	1022	46.88	68
2013-05-05T15:39:16.677-0400	11	521	21	1029	47.17	68
2013-05-05T15:39:17.676-0400	11	523	19	1029	44.02	60
2013-05-05T15:39:18.676-0400	11	519	20	1027	47.64	65
2013-05-05T15:39:19.678-0400	11	521	18	1020	44.97	62
2013-05-05T15:39:20.677-0400	11	517	14	1017	47.87	62
2013-05-05T15:39:21.678-0400	11	517	10	1013	49.91	65
2013-05-05T15:39:22.678-0400	11	518	19	1010	51.34	65
2013-05-05T15:39:23.675-0400	11	516	23	1003	50.93	54
2013-05-05T15:39:24.678-0400	11	514	18	1001	48.54	63
2013-05-05T15:39:25.678-0400	10	515	26	1008	51.04	61
2013-05-05T15:39:26.677-0400	10	516	24	1015	49.25	66
2013-05-05T15:39:27.678-0400	10	513	17	1022	49.58	65
2013-05-05T15:39:28.678-0400	10	1039	21	1029	45.98	66
2013-05-05T15:39:29.678-0400	10	522	17	1028	48.96	65
2013-05-05T15:39:30.678-0400	10	515	27	1021	47.01	61
2013-05-05T15:39:31.678-0400	10	511	22	1014	43.40	67
2013-05-05T15:39:32.678-0400	10	1006	25	1007	47.92	66
2013-05-05T15:39:33.678-0400	9	506	30	999	47.46	65
2013-05-05T15:39:34.679-0400	9	515	14	992	46.19	65
2013-05-05T15:39:35.676-0400	9	517	17	985	47.32	62
2013-05-05T15:39:36.681-0400	9	516	3	978	47.86	66
2013-05-05T15:39:37.681-0400	9	511	31	971	46.98	72
2013-05-05T15:39:38.679-0400	9	513	19	964	47.40	66
2013-05-05T15:39:39.678-0400	9	513	19	957	46.32	68
2013-05-05T15:39:40.679-0400	9	511	21	950	47.03	63
2013-05-05T15:39:41.679-0400	9	514	21	943	44.88	66

2013-05-05T15:39:42.679-0400	9	518	24	936	46.77	65
2013-05-05T15:39:43.679-0400	9	525	24	929	46.27	74
2013-05-05T15:39:44.679-0400	9	522	17	922	45.27	62
2013-05-05T15:39:45.679-0400	9	525	17	915	46.74	73
2013-05-05T15:39:46.678-0400	9	525	16	908	47.58	71
2013-05-05T15:39:47.679-0400	9	519	20	900	45.87	81
2013-05-05T15:39:48.679-0400	9	514	24	893	44.26	72
2013-05-05T15:39:49.678-0400	9	512	20	886	46.72	66
2013-05-05T15:39:50.679-0400	9	520	11	879	48.80	78
2013-05-05T15:39:51.679-0400	9	521	30	872	44.86	69
2013-05-05T15:39:52.678-0400	9	527	0	865	45.61	69
2013-05-05T15:39:53.679-0400	9	525	26	858	45.40	72
2013-05-05T15:39:54.679-0400	9	522	20	851	47.90	77

These data show that this solution can provide the means to examine the association between a health end point, such as HRV, and air pollution concentrations. For example, it can allow researchers and users to examine the data using statistics. As mentioned before, this is just a small sample of data and the results presented here should not be used to infer any conclusions about the nature of these associations. The data and the analyses included are only illustrative and a research design that could capture more extensive results is discussed in the next section.

An initial analysis that could be conducted would be to look for correlations among the data. Table 3 shows a correlation table for the air pollution data. It includes the variables CO (ppb) and PM (thousands of particles per cubic foot). The results show little or no correlation for this case. In a study with a larger data sample, such a result could lead researchers to conclude that PM pollution was being caused by sources other than traffic, which typically account for most of the CO concentrations in an urban environment. Such a result would also allow researchers to disentangle the effects of CO and PM on HRV, given a larger sample of data.

Table 3. Correlation Table for CO and PM data

		CO (ppb)	PM (tppcf)
CO_ppb	Pearson Correlation	1	.004
	Sig. (2-tailed)		.974
	N	68	68
PM	Pearson Correlation	.004	1
	Sig. (2-tailed)	.974	
	N	68	68

Regression modeling can also be used to explore associations between the variables included in Table 2. A linear regression model is presented below, again simply as an illustration of how the data collected by the solution presented to this challenge could be used to explore health and air pollution relationships. The model uses HRV as the dependent variable. It uses CO and PM as

the air pollution concentration variables. It uses sound level or noise to control for a potential confounding factor. And it uses peak acceleration to control for level of activity which is another potential confounding factor. Table 4 summarizes the variables included in the model and Tables 5, 6, and 7 summarize the results of the model. The data included in the analysis consist of a small sample of data which does not allow us to make inferences. However, these tables show that this kind of regression modeling could allow researchers to explore associations between HRV and some of these variables. In this case, only PM appears to be related to HRV but again these results are only illustrative of the kinds of results that might be obtained using larger data samples of more users over more sampling time.

Table 4. Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	Peak_Accel, CO_ppb, Noise_dB, PM ^b		Enter

a. Dependent Variable: HRV

b. All requested variables entered.

Table 5. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.755 ^a	.570	.543	1.47343

a. Predictors: (Constant), Peak_Accel, CO_ppb, Noise_dB, PM

Table 6. ANOVA^a Table

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	181.462	4	45.365	20.896	.000 ^b
	Residual	136.774	63	2.171		
	Total	318.235	67			

a. Dependent Variable: HRV

b. Predictors: (Constant), Peak_Accel, CO_ppb, Noise_dB, PM

Table 7. Coefficients^a Table

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.585	7.138		.362	.718
	CO_ppb	-.004	.031	-.011	-.134	.894
	PM	.016	.004	.427	4.037	.000
	Noise_dB	.040	.076	.045	.524	.602
	Peak_Accel	-.144	.039	-.397	-3.658	.001

a. Dependent Variable: HRV

Future Research

The data presented in this section of the report represents a small sample of example data that can be collected and analyzed by such an instrument configuration. Given more resources and time, this solution to the challenge could be scaled up to provide a wealth of data that could be used for research purposes, as well as for “crowdsourcing” air pollution data to inform the public, similar to what is presently provided by Google Maps for car traffic. As part of our testing of this solution, several team members and volunteers used the hardware to test it and several glitches have already been resolved. The team is confident that the hardware could be perfected to collect reliable field data through more testing and refinement.

As part of a larger community health study the team members could deploy 20-25 sets of sensors and smart phones to adults that would use them in different urban environments around New York City as they go about their daily lives. The hardware can be set up to collect data for periods of 3-4 hours. Having this number of participants in a study would allow the researchers to explore a number of relationships. There is evidence that heart rate variability changes with age (O’Brien et al 1986). Hence, having a range of ages within a healthy adult population would allow the team to explore how the association between air pollution and HRV varies with age. The real time data generated by this solution and using a larger number of users in the range of 25 adults would also allow the team to explore interaction effects between noise and air pollution, both of which are believed to decrease HRV. Such interactions could also vary with age as mentioned above.

In terms of the methods that could be used to explore these associations the team would begin with linear regression models (given normality assumptions log transformations may be required). Other potential models that could be used depending on the data include autoregressive–moving-average (ARMA) models and additive mixed models adjusted for long- and short-term time trends and piecewise linear analyses.

The team has already developed a draft IRB form and a draft consent form that could be implemented if the resources required to conduct a full community health study were secured.

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Deliverables 3

1. Deliver evidence and examples of data handling and processing -- data collected, data processed and algorithms, output data and final format.

See the below description of the AirCasting platform for an overview of how data is collected, processed, transmitted, and outputted in a range of different final formats.

AirCasting is a platform for recording, mapping, and sharing health and environmental data using an Android device. Its component parts include:

- 1) Handheld or wearable sensor packages that monitor health and environmental parameters;
- 2) An Android app which connects with and displays real-time measurements from sensor packages and transmits these measurements to a web server; and
- 3) A website (www.aircasting.org) which maps, graphs, filters, and processes the sensor measurements collected by the app.

Sensor packages connect to the AirCasting app via Bluetooth. Once a sensor package has been connected and an AirCasting session is initiated by the user, the app begins receiving, mapping, graphing, and enumerating the sensor measurements. Sensor measurements are received, geolocated, and timestamped by the app approximately once per second.

At the conclusion of an AirCasting session, the measurements logged by the AirCasting app are packaged as a JSON file and uploaded to a MySQL database server using either the cellular network or a Wi-Fi connection. Data packages vary in size based on the number of sensor measurements contained in a recording session and their transmission rate depends on the bandwidth of the cellular or Wi-Fi connection to which the Android device is connected. Before transmitting the sensor data to the database server, the user must select whether to make their sensor measurements publicly available via the AirCasting website or keep them private.

Logging sensor measurements with the AirCasting app does not require access to a data network as the data is stored locally on the Android device. A data network is only required for

transmitting the data from the device. Also note that sensor data is saved locally on the Android device to minimize data loss in the event of the app crashing or the Android device malfunctioning.

The sensor data logged by the AirCasting app is packaged as a JSON file before being transmitted to the AirCasting web server. The JSON file includes the following data variables recorded at approximately one second intervals:

- Measurement value: the value the sensor is reporting, e.g. “55”
- Sensor package name: the name of the sensor package, e.g. “AirMonitor5”
- Sensor name: the name/model number of the sensor, e.g. “HIH4030”
- Type of measurement: the parameter being measured, e.g. “relative humidity”
- Short type of measurement: an abbreviation of the parameter being measured, e.g. RH
- Unit name: the unit name for that parameter’s values, e.g. “percent”
- Unit symbol/abbreviation: an abbreviation of the unit name for that parameter’s values, e.g. “%”
- T1, T2, T3, T4, T5: threshold values for fitting “measurement values” to the green, yellow, orange, and red color scale which is used to communicate the intensity of “measurement values” to the user.
- latitude
- longitude
- date
- time

AirCasting data has three final formats: 1) sessions can be viewed via the AirCasting app, which displays the data on the “Route Map”, “CrowdMap”, “Graph”, and “Sensors Dashboard” - for an introduction to each interface see video, available online at <http://youtu.be/dRnS0sf3D2A> 2) sessions can be viewed via the AirCasting website, which displays the data on the “Sessions Map” and “CrowdMap” - for an introduction to each see video, available online at <http://youtu.be/dRnS0sf3D2A> 3) sessions can be emailed as CSV files, an example of which is available online at <http://bit.ly/ACexample>.

2. Demonstrate any software. Explain software and how and why it works.

All the code for both the AirCasting website, <http://bit.ly/AirCastingWeb>, and Android app, <http://bit.ly/AirCastingApp>, is open source and available through GitHub using the embedded links. For a demonstration of the software see video, available online at <http://youtu.be/dRnS0sf3D2A>.

The dust sensor algorithm is based on a stepwise adjustment of a running estimate, taken at every one-second interval. The raw detection intervals measured from the sensor are first scaled by some constant, and then the estimate is adjusted proportionally to the difference between itself and the scaled raw detection. When the detection is zero, the estimate decays exponentially to zero. The scaling is such that the estimate rises faster than it falls, which compensates for the sparsity of the raw data from the sensor, especially at low concentrations. Effectively, we heed the greater importance of a positive detection event over zero detection in order to achieve a responsive estimate that does not simply drop to zero in a matter of seconds.

3. Show how data is tracked and monitored while still maintaining privacy as required (i.e. time/date stamps, etc.)

See previous response, “Deliverables 3.1.”

4. Demonstrate how all data is collected, buffered and compiled while maintaining its integrity. Finalists may choose format for submission package.

See previous response, “Deliverables 3.1.”

Category 4

4) Demonstration of responsiveness to community needs

a) Study demonstrates appropriate community input throughout, and health-environment connection of interest addresses community concerns and needs

As part of our solution for the My Air, My Health Challenge we conducted a pilot in New York City for a future community health study investigating the correspondence between exposures to carbon monoxide and fine particulate matter and changes in heart rate variability. The pilot was conducted in partnership with the Newtown Creek Alliance - a community based organization representing the interests of community residents, local businesses, and elected officials who are dedicated to restoring community health, water quality, habitat, access, and vibrant water-dependent commerce along Newtown Creek. Dividing Western Queens from Northern Brooklyn, Newtown Creek is one of the most polluted waterways in the United States and traverses some of the most neglected neighborhoods in New York City before trickling into the East River.

We elected to work with the Newtown Creek Alliance for two reasons: 1) the communities around Newtown Creek are disproportionately impacted by air pollution relative to other communities in New York City (for reference see the below list of air pollution sources), and 2) one of our team members (Michael Heim binder) serves as Chairman of the Board of the Newtown Creek Alliance which ensured the pilot would address existing and well documented community concerns and needs regarding air pollution and local air quality.

The following is a list of hazardous facilities/properties/infrastructures found within one mile of Newtown Creek that contribute to fine particulate matter and carbon monoxide pollution in the neighborhoods surrounding Newtown Creek.

- 17 Point Source Air Emissions Facilities release approximately one million tons of toxic air emissions annually.
- Because of capacity limits in the power grid surrounding Newtown Creek, an unidentified number of businesses supplement the electricity they receive from the grid with power from their own generators. When compared to power coming from the grid, these electric generators produce more pollution per unit of energy created.
- The Creek is bisected by the Brooklyn-Queens Expwy and paralleled by the Long Island Expwy, both of which are busy motorways handling hundreds of thousands of cars a day.
- Creek neighborhoods are traversed by dozens of miles of designated City truck routes. These routes are heavily trafficked with diesel trucks because of the many warehouse facilities, bulk petroleum product distribution facilities, and waste transfer stations located near the Creek.

- 19 Waste Transfer Stations handle 38% of all the waste that goes through transfer stations in New York City. In addition to the truck traffic generated by the waste export business, the heavy machinery used on site to process and sort waste generates additional air pollution.
- There are thousands of buildings with oil burning boilers near Newtown Creek, including clusters of buildings in the Maspeth area that burn the dirtiest grades of heating oil, No. 4 and No. 6.

On February 25th, 2013 three members of our team (Michael Heimbinder, Michael Taylor, and Carlos Restrepo) were invited to present our prototype solution for the My Air, My Health Challenge and recruit volunteer participants for our pilot during a publicly scheduled Newtown Creek Alliance meeting. The announcement for the public meeting can be viewed on the Newtown Creek Alliance website at <http://bit.ly/CitSci> . The slides for the public presentation are available online at <http://bit.ly/MAMHpublic>.

We recruited seven volunteer participants at the meeting and through word of mouth. Because of time and resource constraints, only three of our volunteer participants were able to collect health and air quality data using our prototype solution for the My Air, My Health Challenge.

b) Appropriate and scientifically valid design of research methods

See response, “Category 3”.

c) Study is carried out in a valid manner

See response, “Category 3”.

Deliverables 4

1. Provide input gathered from the community and show how the input was incorporated into the study.

See response, “Category 4.a”.

2. Report of study results

Given the short time frame of the Challenge, we were unable to obtain IRB approval for our community health study and are therefore unable to share the health and air quality data collected by our pilot participant volunteers. However, we are able to report the qualitative feedback they provided in their post-data-collection interviews which primarily concerned how wearable and usable the prototype hardware was. These results are reported in “Category 1.a.i”, “Category 1.b.i”, and “Category 1.c.i & ii”. In addition, an illustrative analysis of data collected by one of the team members is presented under “Category 3”.

Appendix A: AirCasting How to Guide for My Air, My Health Participant Volunteers

Introduction

Thank you for volunteering to participate in the pilot for our planned community health study investigating the correspondence between exposures to carbon monoxide and fine particulate matter and changes in heart rate variability.

You will be using three pieces of equipment to record, display, and share your health and environmental data: an Android smartphone, an AirGo air monitor, and a Zephyr BioHarness 3 physiological monitor. Instructions on how to operate each of these pieces of equipment are detailed below.

If at any point in time you experience difficulty operating the equipment, please call Michael Heimbinder, 917-318-0480, for assistance.

Equipment List

1 Android Smartphone
1 USB to Micro-USB Cable
1 USB Wall Charger

1 AirGo
1 AirGo Armband
1 Anker Battery
1 Anker USB to Multi-Port Cable
1 Anker Micro-USB Adapter
1 Anker Mini-USB Adapter
1 USB Wall Charger

1 Zephyr BioHarness 3 Computer
1 Zephyr BioHarness 3 Strap
1 Zephyr BioHarness 3 Charging Cradle
1 USB to Mini-USB Cable
1 Mini Screwdriver
1 USB Wall Charger

Prepping the AirGo

To stabilize the carbon monoxide sensor it is necessary to plug in the AirGo at least one hour before beginning an AirCasting session. To plug in the AirGo, plug the USB wall charger into an electrical outlet, plug the USB side of the USB to Mini-USB cable into the wall charger, and plug the Mini-USB side into the AirGo. When plugged in the AirGo automatically turns on. To confirm the AirGo is powered on, look for a red indicator light on the front side of the device.

Putting on the BioHarness

To ensure a good connection, liberally wet the thicker sections of the BioHarness strap with water. If it's not already in place, click the BioHarness computer (the small black puck) into the corresponding fitting on the BioHarness strap, making sure to align the copper connections.

Wrap the chest strap around your stomach right side up and clip it to itself. Pull the strap up until it's running across your sternum just below your pectoral muscles and tighten until it is snug but not uncomfortable. Rotate the strap until the BioHarness computer is directly under your left armpit. Then wrap the shoulder strap over your shoulder and clip it to the chest strap. Adjust the tension on the shoulder strap to ensure that it's tight enough to hold up the chest strap but not so tight as to pull it away from your skin, tension should be minimal.

Putting on the AirGo

When you are ready to go AirCasting, disconnect the AirGo from the wall charger. Then plug the Mini-USB adapter into the AirGo, connect the adapter to the coiled USB cable running from the Anker Battery, and push the small transparent button at the top of the Anker battery. The indicator light on the Anker battery will turn green and the indicator light on the AirGo will turn red when everything is successfully connected and powered.

Slide the AirGo armband onto your bicep and tighten as required. Be sure the AirGo is facing away from your body and the intake and exhaust ports on the front side remain clear of obstructions for the entirety of your AirCasting session.

Connecting the BioHarness to the AirCasting App

Turn on the BioHarness by pressing your thumb to the center of the BioHarness computer and holding it there for 3 seconds. You will know the BioHarness is on when the indicator lights begin flashing.

Launch the AirCasting app, press "menu" > "Settings" > "External Devices". Two devices will be listed, press the one that begins "BH", when prompted "Connect?" press "Yes", and wait 10-20 seconds. You will know the BioHarness is successfully connected to the AirCasting app when 1) the blue indicator light on the BioHarness computer begins flashing blue and 2) the AirCasting app "Sensors Dashboard" begins enumerating data from the BioHarness sensors: activity level, breathing rate, core temperature, heart rate, heart rate variability, peak acceleration, and R to R.

If the BioHarness fails to connect to the AirCasting app press "menu" > "Settings" > "External Devices". If the BioHarness is listed as "Connected" press its name and when prompted "Disconnect?" press "Yes". Then turn off the BioHarness by pressing and holding the center of the BioHarness computer. Next, exit the app, launch the "Task Manager" app, press "Kill Selected Apps", then relaunch the AirCasting app and repeat the above directions.

Connecting the AirGo to the AirCasting App

Launch the AirCasting app, press "menu" > "Settings" > "External Devices". Two devices will be listed, press the one that begins "RN42", when prompted "Connect?" press "Yes", and wait 10-20 seconds. You will know the AirGo is successfully connected to the AirCasting app when 1) the red indicator light on the AirGo turns green and 2) the AirCasting app "Sensors Dashboard" begins enumerating data from the AirGo sensors: carbon monoxide, particulate matter, temperature, and relative humidity.

If the AirGo fails to connect to the AirCasting app press “menu” > “Settings” > “External Devices”. If the AirGo is listed as “Connected” press its name and when prompted “Disconnect?” press “Yes”. Then unplug and plug in the AirGo to toggle the power off and on. Next, exit the app, launch the “Task Manager” app, press “Kill Selected Apps”, then relaunch the AirCasting app and repeat the above directions. Note that when you kill the AirCasting app it will disconnect you from all “External Devices” so you will also need to reconnect to the BioHarness.

Starting an AirCasting Session

AirCasting provides four ways to view your sensor data: the “Route Map”, the “CrowdMap”, the “Graph” and the “Sensors Dashboard”. Toggle between the views by tapping the triangular buttons located on the left and right sides of the screen. If you don’t see any buttons, tap the screen once to make them appear; tap the screen again to make them disappear.

Toggle to the “Route Map” or “CrowdMap”. Make sure your GPS is on and your location on the map is accurate. Without a GPS fix you will not be able to record data. Press the “bullseye” button to refresh your location and center the map. Once you have confirmed that your location is accurate and the BioHarness and AirGo are connected, press the “record” button to begin recording data. If you don’t see the “record” button, tap the screen once and it will appear. Note that the smartphone will revert to a sleep state when the display is not in use. The AirCasting app will continue to record data while the phone sleeps.

While Recording an AirCasting Session

While recording your session you will need to do three things:

1) Occasionally check your R to R measurements and make sure the values are between 200 and 2000. If the values are outside of this range then either rewet the strap or adjust the BioHarness strap so it runs snugly across your sternum just below your pectoral muscles and the BioHarness computer is directly under your left armpit. Note that you may get values outside the designated range when you are active or raising your arms above your head. This is to be expected and is perfectly acceptable.

If the values don’t change nearly every second, i.e. they are frozen, then you will need to reconnect the AirCasting app to the BioHarness. To do this press “menu” > “Settings” > “External Devices”. Two devices will be listed, press the one that begins “BH”, when prompted “Connect?” press “Yes”, and wait 10-20 seconds.

2) Occasionally check your particulate matter measurements. If the values don’t change nearly every second, i.e. they are frozen, then you will need to reconnect the AirGo to the AirCasting app. To do this press “menu” > “Settings” > “External Devices”. Two devices will be listed, press the one that begins “RN42”, when prompted “Connect?” press “Yes”, and wait 10-20 seconds.

3) If while observing your measurements or environment you notice something you believe would assist us in evaluating your data - e.g. an anomaly in the measurements or a pollution source - you may elect to make note of it and/or capture a photo by pressing the “share” button,

the icon at the bottom of the screen with two arrows pointing up and away from a circle. If you don't see any buttons, tap the screen once to make them appear; tap the screen again to make them disappear. Note that the "share" button only appears when you are actively recording a session.

Stopping an AirCasting Session

After 3 - 4 hours, when you are done collecting measurements, press the "stop" button. This will prompt you to enter a "title", "description", and "tags". Enter information in these fields if you like then press "Save session". You will then be presented with two choices: "Yes, save and contribute" or "Save but don't contribute". If you want your data to be public select the former; if you want to keep your data private select the latter. Your session data is now stored locally on the smartphone and will begin uploading to the AirCasting.org server.

Sharing Your AirCasting Sessions

Once you've saved your session you will need to Email it to us by doing the following. Press "menu" > "Sessions" > press and hold the name of the session you want to share > press "Share" > "Share file" > select your email program of choice and send your session to Michael Heimbinder, mheimbinder@habitatmap.org.

About the AirCasting User Interface

The "Sensors Dashboard" displays the measurements from all your sensor streams simultaneously. Tap the record buttons next to each sensor stream to toggle recording off/on. Tap the eye icon to select that sensor stream for viewing on the Route Map, CrowdMap and Graph.

The "Route Map" displays your current position as a colored dot with a white outline; dots without an outline are past measurements. A dot's color corresponds to the measurements intensity at a location. Refer to the "Heat Legend" (the colored bar at the top of the screen) to identify the intensity range for a measurement. For example, a yellow dot corresponds to a sound level measurement between 61 and 70 decibels.

The "CrowdMap" displays AirCasting data from all contributors. Each square's color corresponds to the average intensity of all the measurements recorded in that area. Refer to the "Heat Legend" to identify the intensity range for a square. For example, an orange square corresponds to an average sound level between 71 and 80 decibels. If no colors are displayed, there is no data in that area.

The "Graph" displays your measurements over time. Zoom in and out for more or less detail, swipe to pan through the data.

Hint: To adjust the relationship between sensor measurements and display colors tap the "Heat Legend": the colored bar at the top of the screen. To toggle between sensor streams tap the "Avg" "Now" "Peak" circles at the top of the screen.

Charging the Android Smartphone

Plug the USB wall charger into an electrical outlet, plug the USB side of the USB to micro-USB cable into the wall charger and the micro-USB side into the Android smartphone. You will know

the Android smartphone is charging when the indicator light turns orange. When the indicator light turns green the smartphone is fully charged. You will likely need to charge the phone between every session.

Charging the Anker Battery

Disconnect the coiled cable from the AirGo while leaving the mini-USB adapter plugged into the AirGo. Connect the micro-USB adapter to the end of the coiled cable. Disconnect the USB side of the coiled cable from the Anker battery, connect it to the USB wall charger, plug in the USB wall charger, and then plug the micro-USB side of the coiled cable into the Anker battery. You will know the Anker battery is charging when the indicator light turns red. When the indicator light switches off the battery is fully charged. The Anker battery doesn't need to be charged after every session, nevertheless, charging is recommended to ensure the AirGo remains powered for the entirety of every session.

Charging the BioHarness

The BioHarness computer is difficult to remove with your fingers. For this reason, we recommend you use the included mini-screwdriver. Insert the tip of the screwdriver into the notch separating the top of the BioHarness computer from the strap and very gently pry it loose. Insert the BioHarness computer into the BioHarness charging cradle, plug the mini-USB side of the USB to mini-USB cable into the side of the cradle, plug the USB side into the USB wall charger, and plug the wall charger into an electrical outlet. You will know the BioHarness is charging when the orange indicator light begins flashing orange. When the indicator light turns solid orange, the BioHarness computer is fully charged. The BioHarness computer doesn't need to be charged after every session, nevertheless, charging is recommended to ensure the BioHarness remains powered for the entirety of every session.