Tobacco Smoke Pollution on Outdoor Patios

Documenting Sources of $PM_{2.5}$ Using Wearable Imaging Technology

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Background

- The impact of tobacco smoke on air quality in outdoor settings is well documented
- Particulate matter ($PM_{2.5}$) concentration is an established proxy for tobacco smoke but is not specific to tobacco smoke
- It is challenging to discretely observe and document outdoor smoking events on the patio of a public restaurant, café or bar

Objectives

1) Test the feasibility of using wearable imaging technology to discretely collect observational data in outdoor and adjacent indoor hospitality environments
2) Pair observational data with environmental data to understand how observed sources of $PM_{2.5}$ impact air quality

Methods

- Two teams of researchers visited a convenience sample of 21 outdoor hospitality environments in Atlanta, GA, USA
- Inclusion criteria for venues included a smoke-free indoor space, with smoking-permitted patio space, and table service on the patio
- Observations were conducted October 30 to November 2, 2014 between the hours of 12pm and 9pm
- Data were collected for approximately 40 minutes per venue during lunch, dinner, and night time
- One researcher per team wore Pivothead™ glasses with a built-in camera that took pictures every 30 seconds
- A second researcher measured $PM_{2.5}$ concentrations on patios and adjacent indoor and outdoor areas using a Sidepak AM510
- Researchers noted if any patrons or staff commented on their wearable technology

Analysis

- $PM_{2.5}$ concentrations were plotted for time spent on the patio, in the adjacent indoor hospitality space, as well as an outdoor space nearby to measure background/ambient levels (generally on a sidewalk near the venue studied)
- The sequential photos taken every 30 seconds during the visit to each venue were downloaded from the device; the content of the digital images were then assessed and classified as having visible PM2.5 source – including burning tobacco – or not
- Time series air quality measures were then paired with the digital images and average concentrations were calculated for the time periods with elevated $PM_{2.5}$ concentrations (peaks); researchers used the content of the digital images to help understand the source of $PM_{2.5}$ measured

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Results

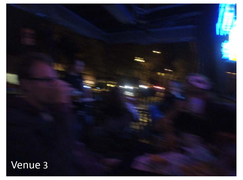
- We observed tobacco smoking at 15 venues
- Data from 11 venues (73%) successfully paired $PM_{2.5}$ readings with photos of concurrent smoking events
- Wearable technology was discrete: throughout the collection period, researchers did not receive any comments or feedback from staff or patrons
- Challenges with the glasses included:
  - Capturing exact start and stop times for smoking events due to poor sightlines
  - Capturing multiple concurrent smoking events in different areas of the patio

Figure 1. Pivothead™ wearable technology

Table 1. Characteristics, air quality, and number of events at venues with smoking

Venue ID	Type of Venue	Sampling Duration (minutes)	$PM_{2.5}$ Events Observed on Patio		Patio Environment $PM_{2.5}$ concentrations (µg/m³)		Ambient Environment $PM_{2.5}$ concentrations (µg/m³)	
			Total	Paired with ≥1 Image	Average	Maximum	Indoor Average	Outdoor Average
1	Bar	54	1	no	1	75	0	0
2	Bar	35	1	yes	8	59	7	11
3	Bar	41	2	yes	22	486	32	6
4	Restaurant	43	1	no	2	40	4	1
5	Bar	36	2	yes	10	152	8	7
6	Bar	41	2	yes	15	547	8	4
7	Coffee shop	40	4	yes	4	49	3	4
8	Bar	33	1	no	7	50	24	6
9	Bar	51	2	yes	3	85	2	2
10	Bar	43	2	yes	38	200	7	3
11	Restaurant	41	1	yes	14	1283	3	2
12	Bar	42	7	yes	14	478	9	11
13	Restaurant	40	3	yes	4	184	9	3
14	Bar	49	1	yes	6	266	5	5
15	Bar	52	2	no	5	381	3	3

Figure 2. Challenges of using wearable technology



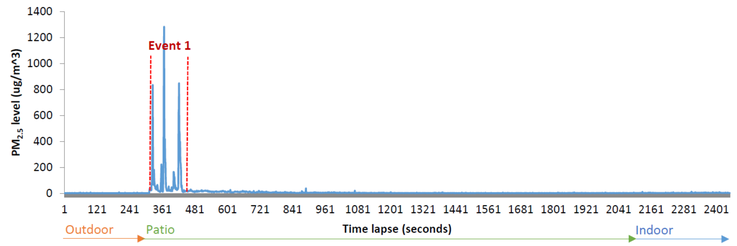
Researchers documented tobacco smoking in observation notes, but the image quality was too low to validate pairing with $PM_{2.5}$ data.

High quality image captured tobacco smoking, but the $PM_{2.5}$ data did not pair. Researchers had to rely on recorded observation notes.

Figure 3. Venue highlights, event identification, and data pairing between observation and $PM_{2.5}$ concentrations

VENUE 11	
Baseline PM2.5 (indoor + outdoor)	3µg/m³ (arithmetic mean)
	3 µg/m³ (geometric mean)
Baseline PM2.5 (indoor)	3 µg/m³ (arithmetic mean)
	4 µg/m³ (geometric mean)
Baseline PM2.5 (outdoor)	2 µg/m³ (arithmetic mean)
	2 µg/m³ (geometric mean)
Average Patio PM2.5	14 µg/m³ (arithmetic mean)
	5 µg/m³ (geometric mean)
Event association	Event 1
Location of Max PM2.5	Patio

EVENT 1	
Max PM2.5 Value	1283 µg/m³
Time of max PM2.5	second 368
Event duration	2 minutes, 37 seconds (second 314 to second 471)
# peaks during event	3
Mean PM2.5 (Arithmetic)	104 µg/m³
Mean PM2.5 (Geometric)	44 µg/m³
Observational Data	Observation notes: One smoker documented at second 317 during the event and at the beginning of patio data collection. 1 smoker noted at minute 0 at the start of Event 1. Pivothead photos: Image 13 (second 361) captures the smoker but it is unclear whether he is smoking in image. Image 14 (second 391) captures the smoker with a cigarette right after the max peak event at second 368.



Conclusions

- Wearable technology was useful for recording tobacco smoking events on outdoor patios without drawing any undue attention to researchers
- Photos supported pairing of observational data with environmental data to understand how tobacco smoke pollution impacted air quality
- Additional written notes are recommended to augment daily recorded observations and to further validate data, particularly when photo quality is low
- Future research would benefit from wearable technology with capacity to take photos second-by-second for a minimum of 30 minutes at a time