Human Mobility Patterns Linked to COVID-19 Prone Locations

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Abstract

To date, there has been little research addressing the impact of human mobility on COVID-19 outbreaks at high-risk places with many long-duration visits, such as bars and restaurants, where large numbers of people congregate in closed spaces for extended periods. Yet, such analysis is key to identifying the best ways to reopen these locations safely. Now that COVID-19 has been around for more than a year, we have access to a vast amount of data regarding people's mobility through aggregated smartphone location data (SafeGraph). We also possess data through various COVID-19 restrictions put in place at different stages of the pandemic—the closure of bars and restaurants in March, their reopening in June, and closure once again in late November.

Using the SafeGraph human mobility dataset, included on the COVID Information Commons (CIC) website [15], we identified and analyzed spatiotemporal patterns in human mobility relevant to bars and restaurants in Minnesota throughout the COVID-19 pandemic. This is challenging due to the denormalized structure of the dataset and numerous external factors that affect human mobility, such as the daily versus weekly trends, special events, and government restrictions. These factors can introduce extraneous data that cloud the relationship between COVID-19 and relevant human mobility patterns. The findings discussed in this paper have the potential to reduce the spread of COVID-19 by providing insights into the correlation between long-duration visits and a COVID-19 outbreak at a location, along with analysis at different stages of the pandemic. Furthermore, our results can be used by policymakers to determine appropriate restrictions that are necessary to minimize COVID-19 outbreaks at high-risk locations and to reduce the spread of future infectious diseases.

1. Introduction

Since the onset of COVID-19 in late 2019, the virus has affected human mobility and the economy in many ways. Countries closed their borders to non-essential travelers, some cities had to quarantine, and many businesses had to shut down and pivot to online customer interactions (the feasibility was largely dependent on a business's sector: the hospitality industry versus the technology industry). These all contributed to unprecedented numbers of people losing their jobs and sharp contractions in economies worldwide—on top of 2.69 million people who have died of COVID-19 as of March 19th, 2021 [1]. During this time, researchers have focused their attention on assisting the broader community by releasing findings and developing projects to expand our knowledge on various aspects of the COVID-19 pandemic. In light of beginning economic recovery, an important question for researchers is how to identify when it is safe to reopen businesses and other places of gathering.

1.1 Related Work

A review of the COVID Information Commons (CIC) NSF COVID Awards and PI Database and the Lingo 4G Explorer showed just a few studies on human mobility patterns as they relate to COVID. For instance, a RAPID NSF-funded project by researchers at Rutgers University is about identifying how efficient COVID-19 quarantine measures were and how to improve them by comparing COVID-19 case numbers and testing procedures across countries with different levels of restrictions on mobility [2]. Two other RAPID projects directly examine mobility patterns. One is a survey of senior citizens about their daily locations and activities [3]. The second is a project with a big data driven approach to find hotspots and isolated populations in a real-time location dataset [4]. In this paper, we analyze weekly mobility patterns at high-risk locations across the state of Minnesota.

2. Methods

2.1 Dataset

Our analysis primarily used SafeGraph's COVID-19 mobility dataset [11] from the CIC resources to access spatiotemporal visit data for business locations. Just in the Minnesota region, SafeGraph has data for over 348,168 individual anonymized devices covering 89,971 point-of-interest (POI) locations across 264 different business categories, with 6.4 million POIs across the US. We also used reports by the Minnesota Department of Health (MDH) [9] that specifically named bars and restaurants—deemed as venues with significant impacts on COVID spread [5, 6]—that were linked to COVID-19 cases during different months.

2.2 Experiments

To better understand the cause of COVID-19 hotspots at hangout places, we developed graphs showing time series of long-duration visits to bars and restaurants in four contexts as follows:

- 15 Places with Outbreaks vs. 15 Places without Outbreaks in June-July (Reopening 1)
- 10 Places with Outbreaks in August (4 Categorized Duration Visits)
- 15 Places with Outbreaks in October (4 Categorized Duration Visits)
- 10 Places with Outbreaks vs. 10 Places without Outbreaks in Jan-Feb (Reopening 2)

Outbreaks are defined as seven unrelated cases from seven different households that only visited one restaurant or bar establishment during that month according to the MDH [10]. Note that bars and restaurants were closed again in November and December 2020 due to the governor's stay-at-home order [7] in response to a significant rise in COVID cases across the state, which is why no analysis was conducted for those months with minimal visit counts to these locations.

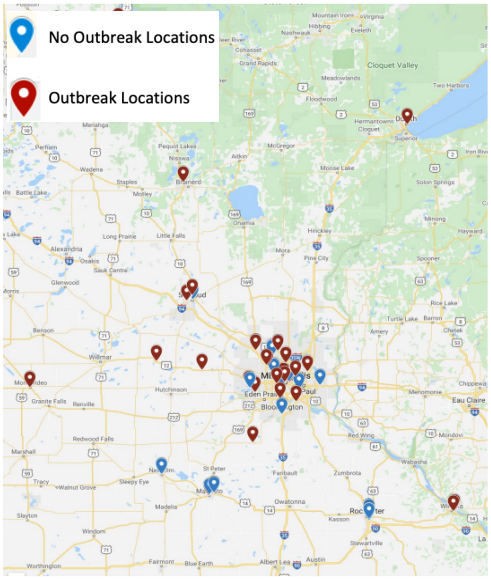

Figure 1: Examined Locations on Minnesota Map

3. Results & Discussions

Figure 1 shows 74 locations of bars and restaurants that we analyzed. The blue marker (no outbreak) locations were selected for

comparison to outbreak locations due to their proximity to outbreak locations and similar number of visits as outbreak locations before the shutdown in March 2020 and once again in November 2020.

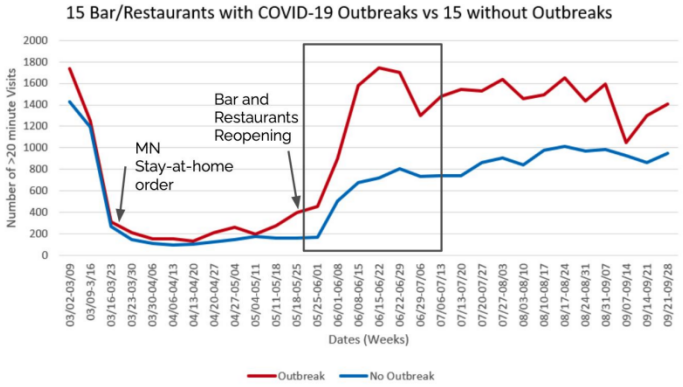

Figure 2: Long-duration visits for outbreak and non-outbreak groups

From Figure 2 on the left, we see an increase in long-duration visits (number of people that visited the location and remained there for over twenty minutes) for both outbreak and non-outbreak groups after Minnesota's phase 3 reopening in June [8]. However, the outbreak group's long-duration visits reached pre-COVID levels of visits (first week of March), whereas the no-outbreak group only reached 50% of pre-COVID levels of visits by June 29th. This suggests that large increases in long-duration visits correlate with outbreaks. The 15 outbreak locations had a total of 783 cases of COVID-19 linked to their establishments in June 2020 alone.

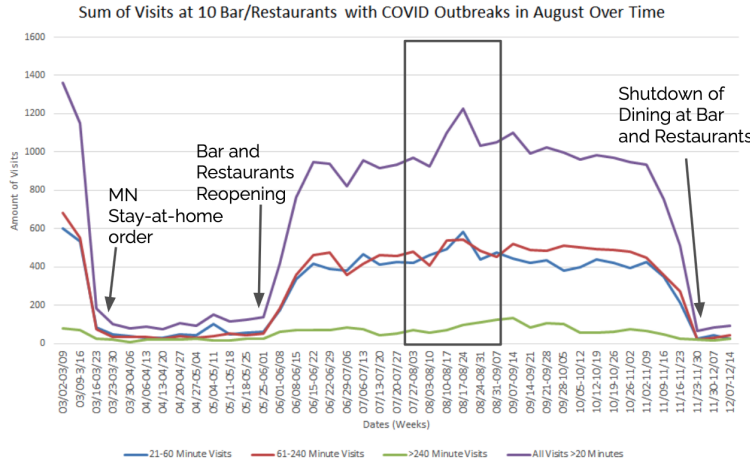

Figure 3: Visits to Outbreak Places in August

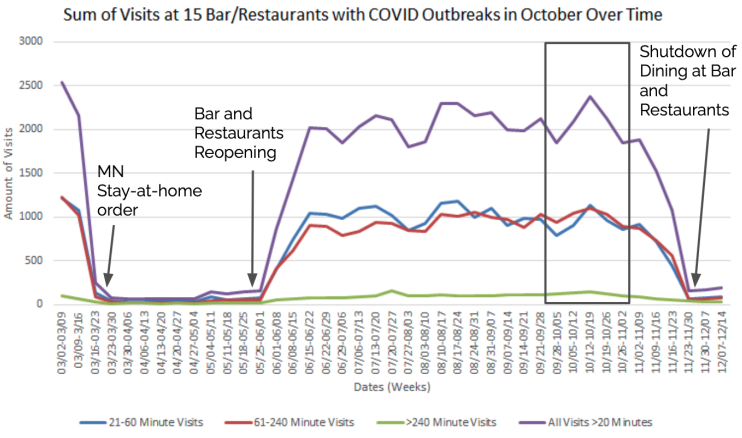

Figure 4: Visits to Outbreak Places in October

We also wanted to see how long-duration visits occurred at outbreak locations during months without major reopenings. Figure 3 and Figure 4 show two different outbreak groups composed of 10 outbreak locations and 15 outbreak locations respectively. Each line trend is for the total number of visits categorized by the duration of that visit in minutes. Both graphs show a multiple-week increase in visits followed by a decline in visits after each peak during the month of reported COVID case outbreaks.

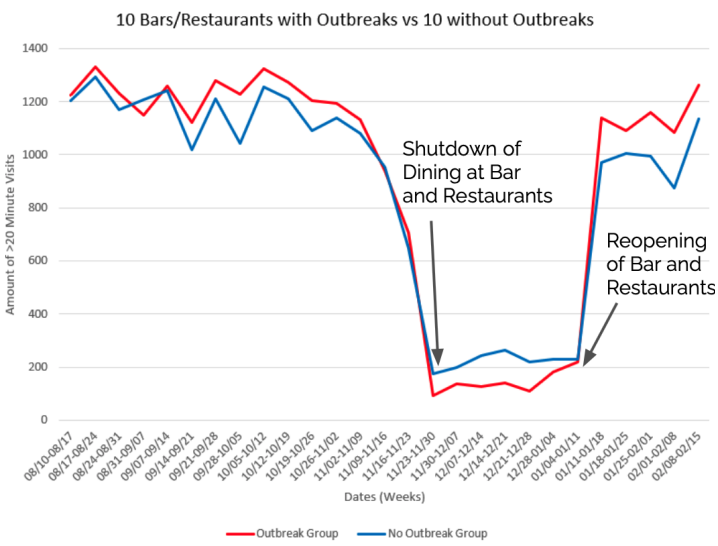

Figure 5: Long-duration visits for outbreak and non-outbreak groups in Jan-Feb

Dining establishments were closed again in November and December of 2020. After they reopened, we compared outbreak versus non-outbreak locations again, this time for January and February of 2021. In this case, the outbreak locations had a 20% higher long visit count than the no-outbreak locations after reopening despite both groups having similar numbers of visits prior to closure.

4. Conclusion & Future Work

From our above analysis and results, we have shown that the number of long-duration visits at high-risk establishments can offer insights into why outbreaks occur at certain locations and not others. We also took into account positive and negative examples by comparing outbreak locations with locations without outbreaks while keeping many variables as consistent as possible (close proximity, similar number of visits prior to outbreak, and the same business category: bars and restaurants). To ensure that the results were not specific to one bar or restaurant, we used multiple groups of 10 or more locations to show that these trends were not just outlier cases but rather a tendency of the entire business category. In future work, we can study the above long duration patterns among disadvantaged racial and socioeconomic groups [12] using demographic data (e.g. US Census) and predict infection rates at finer geographic granularity (e.g. census block groups). Analyzing the correlation between long-duration visits and indoor atmosphere of locations (e.g. amount of air ventilation [13], distance between visitors inside the location, density and crowdedness [14]) could shed light onto other factors seen in association with long duration visits. Lastly, access to COVID-19 infection data for other business categories could strengthen the link between long-duration visits and disease outbreaks at business locations.

Acknowledgments

I would like to thank Gaoxiang Luo, Professor Joydeep Bhattacharya, Professor Shashi Shekhar and his spatial computing research group for their helpful feedback and comments while writing this paper.

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