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Spring 2020 COVID-19 community transmission behaviours around New York City medical facilities

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S U M M A R Y

Background: Epidemiological studies have long been used for infection transmission prevention, but exact patterns of touch behaviours and transportation choices [contributors to community spread of coronavirus disease 2019 (COVID-19)] were previously unknown.
Aim: To investigate individual risk behaviour levels with respect to local COVID-19 infection levels.
Methods: A longitudinal field study recorded behaviours of individuals leaving medical facilities following the New York State's PAUSE order. A subset of those data was analysed herein (4793 records, 16 facilities, 23rd March–17th May 2020). Touched objects and transportation choices were compared over time using Chi-squared tests ($P<0.05$ significance threshold).
Findings: In Week 1, 64.1% of subjects touched at least one environmental object [such as a building door handle (21.8%); traffic light, railing or parking meter (5.6%)]; shared object [such as a vehicle door handle (19.7%)]; personal object [such as a cell phone (4.2%)]; or themselves (0.4%). By Week 8, <35% of subjects touched at least one object, where the greatest reduction was in touching environmental objects. The frequency of touching increased slightly during the observation period for some personal objects such as cell phones. The use of public transportation remained steady (approximately 20%) throughout the study period; for-hire vehicle usage increased from 0% in Week 1 to 7% in Week 8, mirroring a 7% decrease in the use of personal vehicles (from 34% to 27%). Touching and transportation patterns varied significantly by facility.
Conclusions: While this study observed a decline in touch patterns and use of shared modes of transportation, the persistence of many risk-related behaviours suggests that more effective public health policies, including cleaning regimens for public environmental objects and the removal or relocation of frequently touched objects, could help limit the spread of COVID-19.

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Introduction

On 1st March 2020, the first case of coronavirus disease 2019 (COVID-19) was confirmed in New York City (NYC) [1]. Over the ensuing months, NYC became one of the first COVID-19 hotspots in the USA, with an average of >4300 new cases per day from late March to mid-April 2020 [1]. Based on the issuance of a PAUSE order by New York State, most of NYC was shuttered, starting from the evening of 22nd March 2020 [2]. Additionally, in an effort to minimize the transmission of infection, medical facilities were only accessible to patients, healthcare workers and delivery drivers [3]. On the first day of the PAUSE order, NYC had 771 new COVID-19 hospital admissions. Within 1 week, that figure nearly doubled to 1503 [1]. With shortages of personal protective equipment (PPE), healthcare workers became infected with COVID-19 at high rates (representing nearly 11% of all reported cases of COVID-19 in May 2020) [4]. Furthermore, because of hospital capacity constraints, COVID-19-positive patients with mild to acute symptoms were sent home to reserve beds for the sickest patients [5].

At this time, the full nature of COVID-19 was unknown, although person-to-person transmission by respiratory droplets – like other coronaviruses – was suspected from the beginning. Early studies showed that the virus could spread when a non-infected person touched an infected individual or a contaminated inanimate object and then touched their eyes, nose or mouth [6], with laboratory studies showing the virus's ability to survive on common materials for a period of a few hours to several days depending upon the material, thereby demonstrating the risk of transmission via surfaces [7]. Other community transmission mechanisms were linked to transportation choices. The NYC subway system was said to be one of the largest disseminators of COVID-19 'if not the principal transmission vehicle' in the first quarter of 2020 [8].

The National Science Foundation field study Developing Epidemiology mechanisms in Three-dimensions to Enhance Response (DETER) collected >5100 records of observed touch behaviours and transportation choices of people leaving select NYC medical facilities over the 8.5 weeks (22nd March to 19th May 2020) immediately after issuance of the PAUSE order, which was coincident with the spring COVID-19 peak in NYC. This paper analyses those data to identify behaviours that may have facilitated the spread of COVID-19. Specifically, it examines how people interacted with the built environment and their transportation choices, with the aim of providing insights that may inform the understanding of risk and related public health policies.

Methods

Study design, setting and participants

DETER was an institutional review board (IRB)-approved project to gather information about randomly selected subjects (patients, healthcare workers and delivery workers) leaving various hospitals and urgent care clinics in NYC. The observed route of each subject was recorded in a Keyhole Markup Language/Zipped-compatible mapping program along with observations related to gender, time, date, objects touched, and destinations and transportation means selected (Figure S1, see online supplementary material). Subsequently, the data were transferred manually to a spreadsheet and coded (Google Sheets/Microsoft Excel). This paper analyses a subset of that publicly available dataset.

While the study began on 22nd March and ended on 19th May 2020 (and captured 5124 records), the greatest number of observers were in the field over an 8-week period (23rd March to 17th May 2020), producing 4949 records. Of these, 144 subjects returned to the hospital. As this study considered transportation choices, these records were excluded. Of the 4805 remaining records, 12 were excluded due to incomplete touch data. The final dataset contained 4793 records (2442 females and 2351 males). Cumulatively, across all facilities, the daily collection averaged 87.5 subjects (range 0–165). In Week 1 (23rd March to 29th March 2020), there were only six observers at five medical facilities in the field (three hospitals and two urgent care clinics). In Weeks 2–7 (30th March to 17th May 2020), this increased to 16 observers regularly observing behaviours of randomly selected subjects (patients, healthcare workers and delivery workers) leaving 16 medical facilities (eight hospitals and eight urgent care clinics) in Brooklyn, the Bronx, Queens and Manhattan. For a more nuanced understanding of the data, four facilities were analysed individually (Figures S2 and S3, see online supplementary material).

Touch data and analysis

In this study, objects touched were clustered into five categories: (1) 'personal objects', such as cell phones, cigarettes, personal care items (such as make up, tissues and hand sanitizer) and clothing; (2) 'environmental objects', defined as fixed objects such as a building door handle, bench, fence, mailbox, surface, traffic light post, trash can, or wall; (3) 'self' (such as the individual's face, hair or head); (4) 'shared objects', defined as objects that were not fixed and which multiple people could touch, including a vehicle door handle and delivery packages; and (5) 'other'. The number and percentage of subjects who touched objects in each category were calculated for each week by gender and facility. The total percentage of subjects who touched objects in each category across all the facilities was also calculated by week and gender. To contextualize this information, these data are plotted together with the 7-day average numbers of new COVID-19 hospitalizations in NYC [1].

Transportation data and analysis

For this analysis, transportation was categorized into five groups: use of public transportation (bus and subway); driving/riding in a personal vehicle; riding in a for-hire vehicle (such as a taxi); walking; and riding a bicycle. The number and percentage of subjects who used each mode of transportation were calculated for each week by gender and facility. The total percentage of subjects who used each transportation choice for all the facilities combined was calculated by week and gender.

Statistical methods

Differences in the percentage of subjects who touched objects or who did not touch objects during observation between Week 1 and Week 8 were compared using Chi-squared analysis. Similarly, the differences in the percentage of subjects who used different modes of transportation were also

Table I
Distribution of touch behaviours

Category		Week 1: 23rd–29th March 2020 (284 records)	Week 8: 11th–17th May 2020 (569 records)	Weeks 1–8: 23rd March–17th May 2020 (4793 records)
No touch[a]		35.9%	65.6%	55.8%
Touch data				
Self	Face, hair, eyes	0.4%	1.2%	1.4%
Personal objects	Cell phone	4.2%	7.9%	10.4%
	Cigarettes	3.5%	4.0%	3.8%
	Clothing, glasses, mask, food/drink and personal care items	8.1%	3.3%	5.9%
Environmental objects	Door handle (building)	21.8%[b]	6.3%	9.5%
	Traffic light post, hand railing, fence and parking meter	5.6%	2.8%	3.5%
Shared objects	Shared objects (stretcher, stroller, food truck)	0.7%	0.7%	1.5%
	Packages and deliveries	1.4%	2.6%	1.4%
	Door handle (vehicle)	19.7%	10.7%	11.2%

[a] The percentage of individuals observed who did not touch any items. Some individuals touched more than one item.
[b] If Wyckoff Heights Medical Center had implemented an automated door before the PAUSE order, this figure would most likely be closer to 15.5%.

compared using Chi-squared analysis. For all analyses, $P<0.05$ was considered to indicate significance.

Results

Touch patterns

On average, across all 16 facilities and 8 weeks of observation, 44.2% of subjects touched one or more objects: one touch (35.6%), two touches (7.1%), or three or more touches (1.5%). As shown in Table I, subjects touched personal objects most frequently (20.1%), with cell phones (10.4%), cigarettes (3.8%) and personal care items (1.5%) being the most common items. Of the 11.6% of subjects who touched environmental objects, the majority touched a building door handle (9.5%), while others touched traffic light posts (0.8%) and trash cans (0.5%). In total, 11.2% of subjects touched a vehicle door handle, and the majority of those vehicles (81.1%) were personal vehicles. Only 69 (1.4%) subjects touched themselves during the observation period, making 'self' the least frequently touched category.

Over the 8-week observation period, the level of touching decreased significantly ($P<0.001$) from >60% of subjects touching at least one object in Week 1 to <35% in Week 8 (Figure 1). The greatest reduction in objects touched was for environmental objects, such as a building door handle (from 29.2% to 9.1%, $P<0.001$); and shared objects, such as a vehicle door handle (from 21.5% to 14.1%, $P<0.01$). The percentage of subjects touching their faces, hair and clothing remained consistently low (<1.7%). For some personal objects, the frequency of touching increased slightly during the observation period. For example, in Week 1, 4.2% of subjects touched their cell phones, and that figure was 7.9% in Week 8 ($P<0.05$).

Touch patterns varied by site (Figure S2, see online supplementary material). For example, CityMD Fresh Meadows Urgent Care Clinic in Queens had the highest percentage of subjects who touched nothing over the 8 weeks, never falling below 92.2%. In contrast, at Wyckoff Heights Medical Center in Brooklyn, only 15.1% of subjects touched nothing, while 23.7% touched a personal object and 51.6% touched an environmental object, most commonly a door handle. During the week beginning 27th April 2020, Wyckoff Heights Medical Center in Brooklyn modified the observed exit to have an automatic door, which instantly decreased touch rates (Figure S2d, see online supplementary material). As the observations from the DETER study were not shared with the medical facilities during this period, the change of door mechanism was not influenced by this study.

When analysed by gender, the percentages of men and women who were observed to touch at least one object were similar (44.9% and 43.7%, respectively), and they touched the same number of objects: one object (35.3% of men and 35.8% of women), two objects (7.4% of men and 6.8% of women), or three or more objects (1.9% of men and 1.1% of women). The level of touching over time was also similar between men and women, although the objects they touched differed. Over the observation period, both men and women touched cell phones (9.3% and 10.8%, respectively) and building door handles (10.4% and 8.1%, respectively) at similar rates, but men touched cigarettes more than twice as often as women (5.0% and 2.4%, respectively), which is largely reflective of the current gender breakdown of smokers in NYC (17% male and 9% female) [9].

Transportation choices

Of the initial 4805 individuals who did not return to the medical facility, a further 1180 records were excluded because final destinations were considered ambiguous: 'other' (227 records), 'parking lot' (397 records), 'tent (hospital)' (30 records), 'street' (370 records) or 'not recorded' (156 records). As bicycles were not clearly labelled as 'personal bicycle' or 'shared/rented bicycle', the 21 records that noted bicycle usage were also removed, leaving 3604 records (1887 females and 1717 males) for transportation analysis.

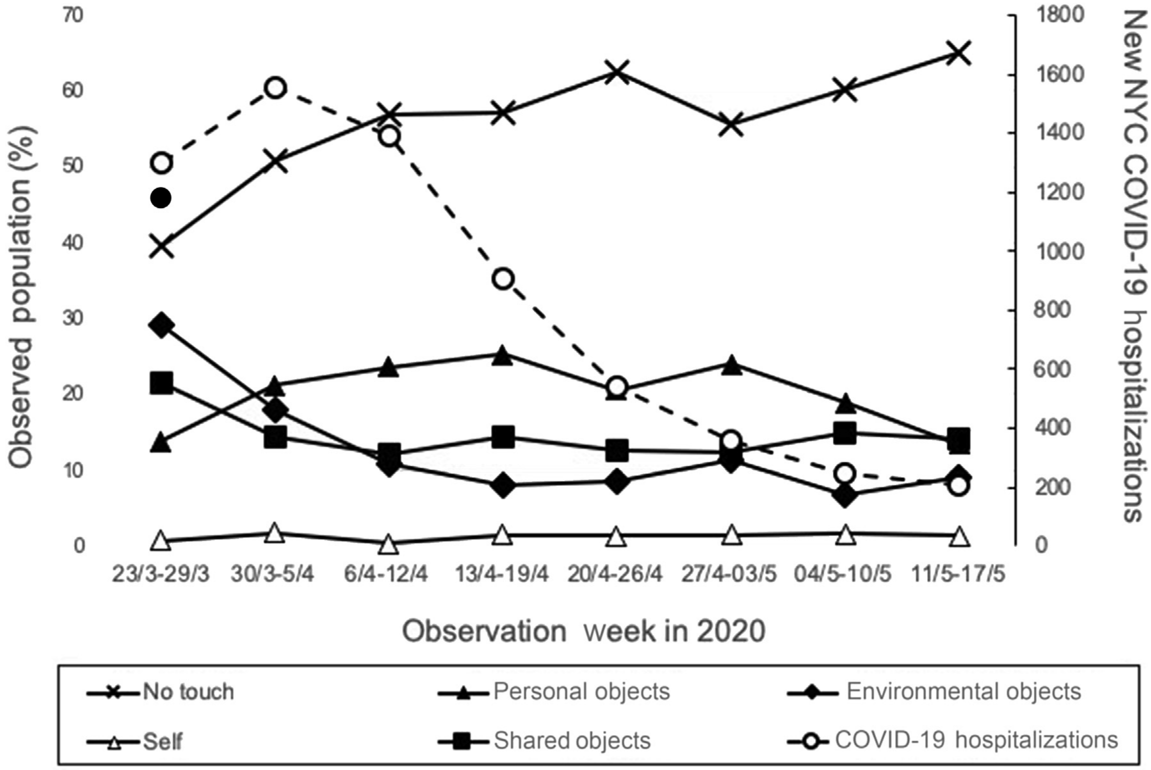

Figure 1. Patterns of touch behaviour for individuals leaving New York City (NYC) medical facilities from 23rd March to 17th May 2020. As a reference, the number of coronavirus disease 2019 (COVID-19) hospitalizations in NYC is also plotted. Black circle indicates the percentage of subjects in Week 1 who did not touch any objects, including subjects who only touched the door handle at Wyckoff Heights Medical Center, to show the predicted value for the percentage of subjects who would not touch an object had the medical center switched to an automated door prior to the COVID-19 pandemic.

Averaged across all facilities and the 8-week study period, the most common transportation choices were walking (41.9%) followed by personal vehicle (32.5%) (Figure 2). A further 19.6% of subjects used public transportation (10% subway and 9.7% bus), and 5.9% used a for-hire vehicle. Transportation choices also changed over the 8-week period (Figure 2). During Week 1, 34.3% of subjects used personal vehicles, which decreased to 26.9% in Week 8; this change was not significant ($P<0.1$). In contrast, the percentage of subjects choosing for-hire vehicles increased from 0% in Week 1 to 7.2% in Week 8. The percentage of subjects walking did not change significantly (45.9% in Week 1 vs 48.8% in Week 8; $P>0.1$). The use of public transportation had a small downturn, with 19.9% in Week 1 (9.4% subway, 10.5% bus) vs 16.5% in Week 8 (7.5% subway, 9.1% bus). Individual transportation choices varied by gender. Over the whole observation period, more men used personal vehicles than women (36.3% vs 29.2%), and women were 1.3 times more likely to use public transportation than men (21.7% vs 16.3%) ($P<0.001$).

Not only did transportation choice vary longitudinally and by gender, but there were also notable differences by facility (Figure S3, see online supplementary material). For example, at CityMD Fresh Meadows Urgent Care Clinic in Queens, 93.1% of subjects left in personal vehicles in Week 1, but this decreased to 73.7% in Week 8, with more subjects walking (21.1% in Week 8) and little change in public transportation. In contrast, at NYU Langone Brooklyn Hospital, 74.1% of subjects left in personal vehicles in Week 1, and this figure decreased to 38.9% in Week 8. At that site, while walking increased (7.4% in Week 1 to 22.9% in Week 8), the use of public transportation increased dramatically (18.5% in Week 1 to 31.3% in Week 8), so the change was not wholly explained by an improvement in the weather.

Discussion

With Governor Andrew Cuomo's mandatory PAUSE order on 22nd March 2020, New York became one of the first states in the USA to go into lockdown to reduce the transmission of COVID-19 [2]. According to Google's mobility trend data [10], the percentage of New Yorkers visiting retail and recreation facilities, grocery stores and pharmacies, parks, transit stations and workplaces declined precipitously. For example, by 23rd March 2020, the percentage of subjects going to transit stations and workplaces in Manhattan had decreased to 23% and 25% of baseline, respectively [10]. Despite these changes, over the next 4 weeks (23rd March to 19th April 2020), NYC saw an average of >1000 new COVID-19 hospitalizations each day [1]. Hospitals and urgent care clinics became epicentres of COVID-19 over the next 2 months.

This analysis of an observational study of 4793 individuals leaving medical care facilities in NYC between 23rd March and 17th May 2020 included many people at high risk for infection, including medical facility employees, patients, and essential workers delivering goods and services. This study identified a high frequency of behaviours, such as contact with shared environmental objects (such as door handles) and potentially

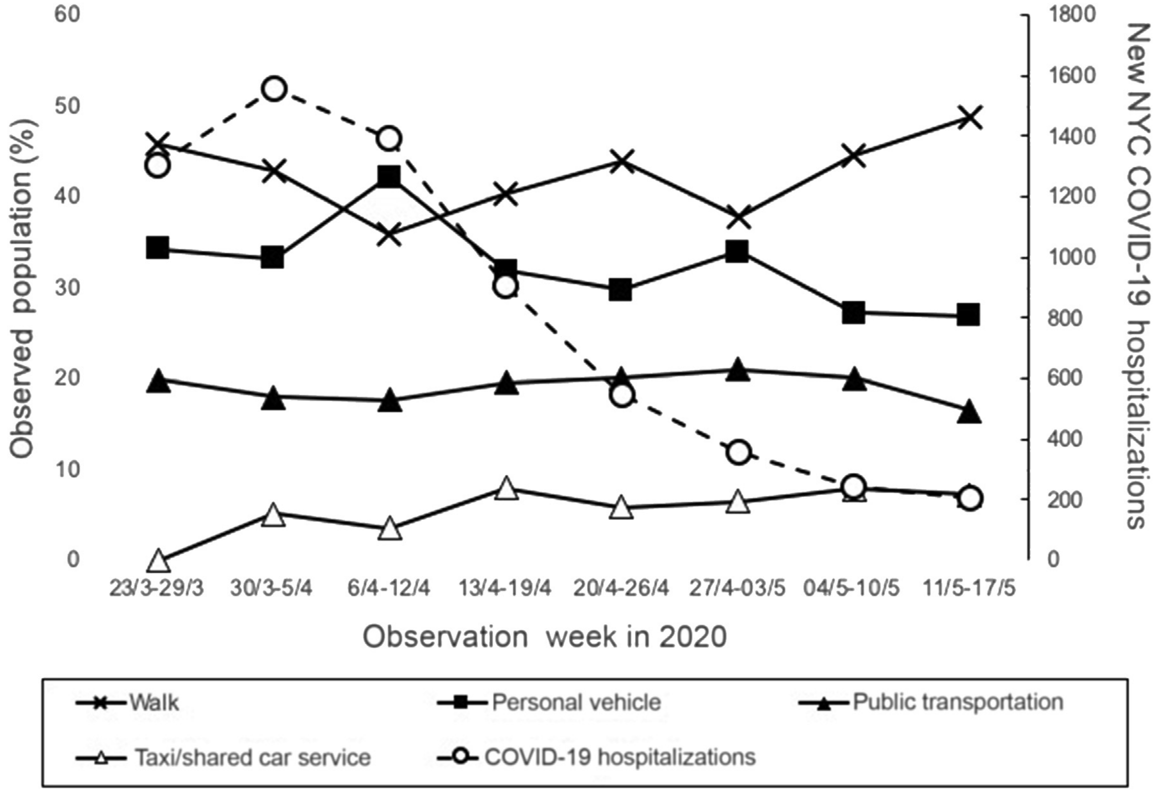

Figure 2. Modes of transportation used by individuals leaving New York City (NYC) medical facilities from 23rd March to 17th May 2020. As a reference, the number of coronavirus disease 2019 (COVID-19) hospitalizations in NYC is also plotted.

contaminated personal objects (such as cell phones), as well as shared modes of transportation that could increase community transmission. These behaviours decreased over time, but still persisted amongst observed individuals a full 8 weeks after the commencement of the lockdown, despite public health warnings about the transmission of COVID-19.

Studies have shown that individuals may get infected by touching contaminated surfaces then touching their eyes, noses or mouths before washing their hands [6], and that severe acute respiratory syndrome coronavirus-2 can reside on surfaces such as plastics and stainless steel for up to 2—3 days [7]. While not the primary means of transmission, the US Centers for Disease Control and Prevention identified doorknobs, counters and tabletops as high-risk surfaces, with their contamination leading to the transmission of COVID-19 [11]. Patterns of touch behaviour of doors, chairs and horizontal working surfaces have also been observed as possible sources of transmission in medical clinics [12], with one study showing high levels of surface contamination in the hospital room of a patient with COVID-19 [13]. In the present study, in Week 1, almost one-third of observed individuals leaving a medical care facility touched an object that was commonly touched by others without intervening cleaning. These included door handles, street lights, parking meters and hand railings. The selection of door mechanisms and door designs can reduce the risk of transmission. For example, one study showed that the onward transmission of bacteria on door handles in a hospital environment was lower with large push plates than with ‘pull’ door handles [14].

While the incidence of individuals touching shared and environmental objects decreased during the observation period, contact with personal objects, such as cell phones, remained high. Studies have shown that, on average, people pick up their cell phones as often as 96 times per day [15] and rarely wash them [16]. When they put their cell phones to their faces, they can introduce bacteria and viral droplets into their eyes, nose or mouth. In a medical environment, as people touch their cell phones without washing them or their hands, cell phones can act as a reservoir of transmission of potent pathogens [16]. In fact, when the cell phones of 386 healthcare workers were swabbed early in the pandemic, 316 of them (81.8%) grew bacterial pathogens [16].

Outside of medical facilities, public transportation sites have been identified as among the highest risk places for acquiring COVID-19 because of touching shared surfaces such as kiosks, touch screens and handrails and the inability to maintain social distancing [11]. In this study, 19.1% of subjects leaving medical facilities used public transportation. Before the COVID-19 lockdown, approximately 56% of NYC’s population, on average, used public transportation in a given week [17]. The lower figure in Week 1 of this study presumably reflects some change in behaviour in response to public health warnings early in the pandemic combined with the PAUSE order.

Across NYC, the use of for-hire vehicles dropped considerably between February and April 2020: the number of taxi trips declined from 217,000 per day to 8000 per day, and ride-hailing services declined from 749,000 to 144,000 per day [18]. A study of 240 NYC drivers found that one in four had a family member who had coronavirus symptoms, and two-thirds of all drivers reported not having sufficient PPE to work safely [19]. Moreover, not all vehicles were fit for proper social distancing

[11]. At the start of this study, ride share services fell to zero and increased only modestly during the study period (reaching 7% by Week 8).

These findings must be considered within the limitations of this study, specifically with regard to its timing, duration and the opportunistic observational method. Specifically, there are no baseline data about behaviours prior to the COVID-19 pandemic. Instead, other public data sets, including Google's mobility data [10] and previous published studies, serve as baseline references. The study data are observational with limited sampling by 16 different observers, and each subject was observed by only a single observer. To minimize variations in measurement and observation, all observers met on video conference calls throughout the data collection period. All data were checked for consistency by two independent researchers during the data cleaning process. However, observers could not see everyone leaving the facility, so they were instructed to choose people at random, creating the possibility of sampling bias. Lastly, the observers were instructed not to attempt to identify the subject's potential role (patient or type of employee), which limits further characterization.

In conclusion, this study of 4793 individuals outside 16 medical facilities in NYC in Spring 2020 demonstrated that despite public health warnings at the onset of COVID-19 in the USA, individuals departing high-risk environments such as medical centres demonstrated behaviours that could contribute to the spread of COVID-19 in the community, primarily through contact with shared objects and shared modes of transportation. Over the 8-week observation period, there were indicators of increased perception of risk. For example, rates of touch decreased, especially door handles (20% decrease from Week 1 to Week 8) and vehicle door handles (7.4% decrease). However, observed individuals continued to touch certain items, including cell phones, at near-constant rates, and the percentage of individuals riding in for-hire vehicles increased from 0% in Week 1 to 7% in Week 8, which aligns with a 7% decrease in the use of personal vehicles, an arguably safer transportation choice. These two examples demonstrate that behavioural response to risk was not wholly consistent, as has been observed in some non-COVID-19 studies. As the subjects were not interviewed, the motivations and rationale for their actions could not be fully ascertained (for example, perhaps individuals were unaware that the use of cell phones could be a risk) [20,21]. In summary, the observational results from this DETER data set can be used to inform analyses of infectious disease transmission with epidemiologic models [22–25]. Furthermore, the results can be used to advance more effective public health policies and guidelines that include cleaning regimens for public environmental objects and the removal or relocation of frequently touched objects to help limit the spread of COVID-19.

Author contributions

S-AKL: conceptualization, methodology, formal analysis, data curation, writing - original draft, visualization. DL: conceptualization, methodology, formal analysis, investigation, resources, data curation, writing - original draft, writing - review & editing, visualization, supervision, project administration, funding acquisition.

Conflict of interest statement

None declared.

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Ethical approval

The study was an IRB-approved project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.infpip.2021.100158.

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