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Australia can use population-level mobility data to fight COVID-19

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Abstract:

"Stay-at-home" orders are a keystone of the COVID-19 response, but are shrouded in controversy. Apple is publishing population-level mobility throughout the pandemic. We mapped the mobility data against public health interventions worldwide. On average populations decreased movement below baseline 13 days prior to "stay-at-home" orders, in Sydney it was 8 days, in Auckland 11 days. Even in cities with minimal governments restrictions, such as Stockholm and Rio de Janeiro this was true. Worldwide this decrease in movement coincided with Lombardy's rising COVID-19 death toll, however Hong Kong and Singapore, pandemic-experienced cities behaved differently, with earlier and ongoing decreased movement. When planning of the "second-wave" we need to be innovative and population-level mobility data can be part of the ongoing public health response.

Article:

"Stay-at-home orders", or the lack thereof, have divided governments and the political sphere worldwide. US[1] media has reported US populations decreased their movement prior to stay-at-home orders. We looked at mobility data from major cities worldwide, including Australia, and saw the same pattern consistently replicated. Why is this so?

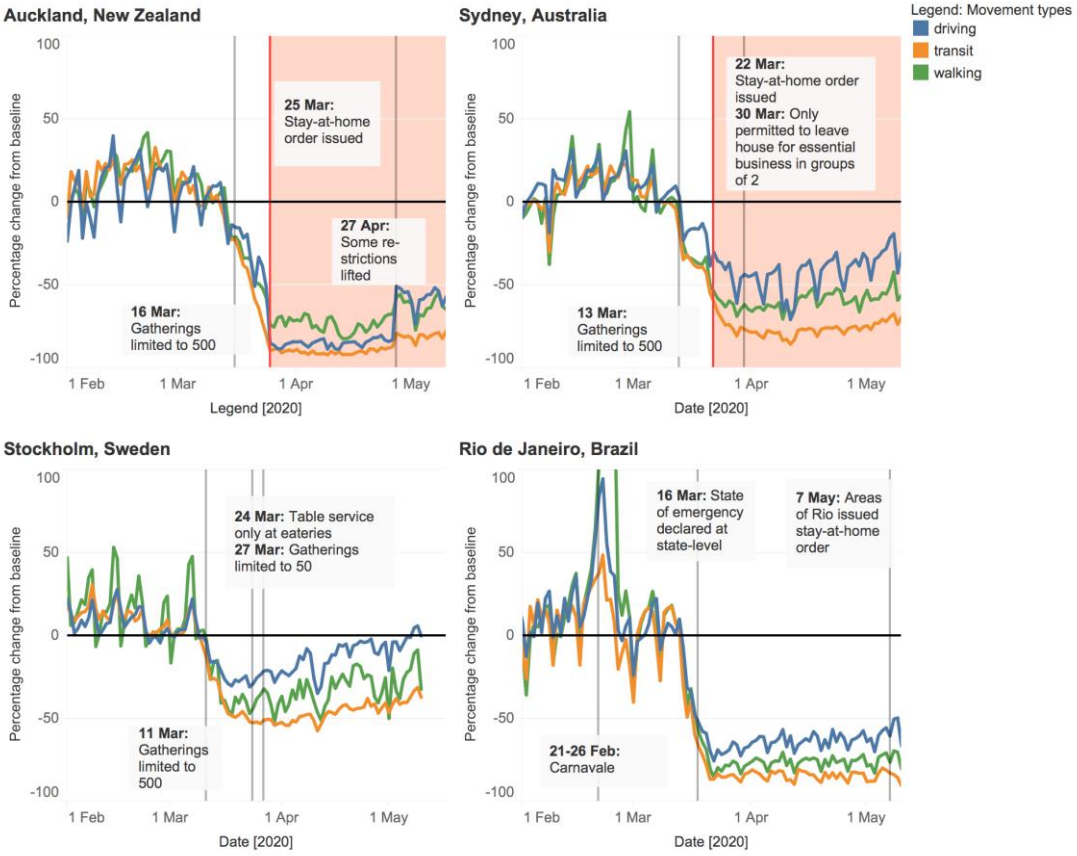
Apple mobility data[2] was used as a measure of social mobility and was assumed to correlate with social distancing population observance. We extracted available data for twenty-two cities across nine regions from all six populated continents in a systemic manner to gain a broad cross-section. This data was then mapped against local government action taken from official websites.

We found worldwide populations reduced their movement prior to and even without stay-at-home orders (Figure 1[2,3,4,5,6], see sFigures 1-9 Supplementary Appendix). Across all cities examined, movement below baseline was seen on average 13·1 days[2], with a median of 9 days, prior to government enforced stay-at-home orders. Mean reduction in walking prior to stay-at-home orders was 45·2% (range 22·0-77·2%[2]). For the majority of cities examined movement voluntarily decreased sharply around March 12[2], which in any other situation would appear coordinated and uniform to military-level precision (Figure 1[2,3,4,5,6], see sFigures 1-9 Supplementary Appendix). In Sydney, Australia's COVID-19 hotspot, population movement dropped below baseline on 14/03/2020, prior to Prime Minister Morrison telling us to "stay-at-home", and nine-days prior to closure of restraurants[5]. The consistency of this data across diverse populations and environments suggests this behaviour is cannot only be driven by strict government restrictions or political pressure within regions. Many factors may have contributed to this, including minor local public health action e.g. limiting mass gatherings, school closures. However, it also coincided with widespread reporting of sharp increases in COVID-19 deaths in the Lombardy region of Italy by March 17 (1625 reported deaths[7]). This near-instantaneous mass behaviour change is significant, it took 50 years and billions of dollars to reduce smoking rates[8], and John Snow[9] days to garner community support to remove the Broad Street pump handle, both in the face of robust epidemiological evidence. Why did we all just go home?

We postulate the global mass media reiterating virus seriousness, broadcasting almost real-time images of full ICUs and dying families into people's living rooms, in conjunction with minor public health restrictions, sparked fear and drove mass behaviour change. Even in cities with minimal restrictions, such as Stockholm there was an average transit decrease of 46·7%[1,4] in April (Figure 1[2,3,4,5,6]). Rio de Janeiro, a city with conflicting government advice and minimal restrictions[3], across April there was an average 75·7% decrease in walking[1] (Figure 1[2,3,4,5,6]). Hong Kong (HK)[10], a city that did not deploy a stay-at-home advisory but with direct transport and cultural links to Wuhan and previous experience with SARS epidemics, movement dropped below baseline on January 23 (see sFigure 5 Supplementary Appendix), well before other cities with an

ongoing reduction in transit walking of over 50%[1]. Singapore[11,12] (see sFigure 5 Supplementary Appendix) with a similar history of SARS showed a parallel picture to HK suggesting past experience, like SARS, also drives risk perception and behaviour. Individual and community risk perceptions will likely determine behaviour as lockdown restrictions ease. Governments planning for re-opening or the "second wave", need to combat complacency and "social distancing fatigue". Behaviour in HK and Singapore suggests prior pandemic experience can lead to early voluntary social distancing. However, government restrictions may be needed for sustained social distancing. As pandemic-naïve populations with low restrictions, such as Stockholm and Atlanta[13] (see sFigure 1 Supplementary Appendix) have up-trending mobility[1]. Mobility data is potentially an effective tool for monitoring population behaviour that informs public health action. As we face Australia faces the "second-wave" public health officials need to be innovative, utilising this free, publicly available, almost-real time resource could be part of the solution.

Figure 1: population-level mobility data mapped against government action[3,4,5,6]:



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Supplement – Online only

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Acknowledgements and Funding

This manuscript was the result of an unfunded investigator-initiated investigation.

Supplementary methods:

Data sources

The Apple Mobility Data reports the relative volume of directions requests per region, sub-region, or city compared to a baseline volume on 13 January 2020, divided by movement type, driving, transit, walking. The definition of day is midnight-to-midnight, US Pacific time. Cities are defined as the greater metropolitan area and their geographic boundaries remain constant across the data set. Eight of the cities (Santiago de Chile, Johannesburg, Casablanca, Mumbai, Riyadh, Tel Aviv, Buenos Aires, and Hong Kong) had driving and walking data available only. Data is anonymous and not traceable to an individual user.

We extracted data from the 13 January to 10 May 2020. We did not extract data beyond 10 May 2020 as data for 11 and 12 May 2020 was unavailable.

Region selection

The world was divided into nine regions: Nordic, Western Europe, Mediterranean, North America, South America, Oceania, Asia, Africa, and Middle East.

It was then analysed what cities had Apple mobility data available. Notably, Africa, South America and the Middle East had limited options. Once this was done a number of cities were excluded to lack of public health data. Then the top global cities[8] from each region were selected. Additionally, cities diverse in culture, population-size, climate, governmental structure, and economy were selected.

These cities were:

Nordic cities: Stockholm, Helsinki

Western European cities: London, Paris

Southern European cities: Rome, Barcelona

North American cities: New York City, New Orleans, Atlanta, Toronto

South American cities: Rio de Janeiro, Buenos Aires, Santiago

Oceania cities: Auckland, Sydney

Asian cities: Hong Kong, Singapore, Mumbai

African cities: Johannesburg, Casablanca

Middle Eastern cities: Riyadh, Tel Aviv

Public health data

Information regarding governmental interventions was extracted from the governmental websites of each region, these were one or a combination of the public health department website, general government department website, or governor's website. The date listed in the images is the date the intervention came into place, not when announcement date.

A stay-at-home order was defined as widespread regional restriction of movement, or strong governmental advice to stay-home. Days before stay-at-home advisory was defined as number of consistent days prior to order being put into place where all movement measures were below baseline. If no stay-at-home order was in place, then it was the first of five days where all movement measures were below baseline, this was used to record when movement dropped below baseline. These cities were not included in the movement decrease prior to stay-at-home advisory analysis.

All data used in this report is publicly available.

Statistical analysis

The data for the fourteen cities was extracted from the global Apple mobility file. On extraction, it was listed as whole number of 100, subtracted 100 from every data point to present as a percentage.

Continuous variables are presented as a mean (standard deviation), median (interquartile range) as appropriate.

Statistical analysis was completed using Microsoft *Excel for Mac (Version 16·37).*

Data visualisation

The data from each city was tabulated individually and *Tableu Desktop – Professional Edition (Version 2020.2.0)* was used to generate and annotate graphs.

Data was only graphed from the 1 February 2020 to better represent data.

Limitations

Our analysis has limitations as Apple mobility data is a crude measure of movement and social distancing uptake in the population. It will be impacted by Apple product usage within the population, and usage of Apple maps for daily movement. There will be variability in volume, consistent with normal, seasonal usage.

Supplementary Tables

sTable 1: Date of movement below baseline

City	Date movement was below baseline	Number of days prior to stay-at-home order
Atlanta	15/3/20	8
Auckland	14/3/20	11
Barcelona	14/3/20	1
Buenos Aires	14/3/20	6
Casablanca	15/3/20	5
Helsinki	9/3/20	7
Hong Kong	23/1/20	N/A*
Johannesburg	15/3/20	11
London	15/3/20	8
Mumbai	8/3/20	15
NOLA	12/3/20	10
New York City	14/3/20	8
Paris	8/3/20	9
Rio de Janeiro	14/3/20	N/A*
Riyadh	13/3/20	24
Rome	1/3/20	7
Santiago	15/3/20	11
Singapore	24/1/20	74
Stockholm	11/3/20	N/A*
Sydney	14/3/20	8
Tel Aviv	11/3/20	14
Toronto	7/3/20	11
Mean	12/3/20	13·05 (15·5)
Median	13/3/20	9·00 (3·5)

*No stay-at-home advisory issued in that region

Data are numbers, or dates. Mean (SD), or median (IQR). SD and IQR not appropriate for dates.

sTable 2: Mean reduction in movement below baseline prior to stay-at-home order by movement type

City	driving	transit	walking
Atlanta	-28·29	-45·88	-32·11
Auckland	-29·03	-45·32	-35·25

Barcelona*	-64·17	-40·36	-63·31
Buenos Aires*	-34·20		-52·06
Casablanca*	-50·50		-54·12
Helsinki	-17·60	-19·81	-21·98
Johannesburg	-30·79		-31·85
London	-37·59	-57·59	-54·32
Mumbai*	-33·29		-37·57
New Orleans	-50·16	-46·71	-77·21
NYC	-37·05	-67·38	-55·07
Paris	-38·15	-24·32	-45·30
Riyadh*	-47·97		-40·38
Rome	-17·79	-30·88	-26·24
Santiago*	-57·06		-69·32
Singapore	-22·06	-34·57	-31·91
Sydney	-19·89	-39·43	-35·58
Tel Aviv*	-53·41		-55·15
Toronto	-37·10	-55·71	-39·15
Mean	-37·16 (13·64)	-42·33 (13·87)	-45·15 (15·05)
Median	-37·05 (20·41)	-42·85 (15·3)	-40·38 (21·01)

**Transit data not available for these cities*

Date are n (%), median (IQR), or mean (SD).

sTable 3: Mean reductions in movement by month and movement type

City	Mean movement reduction in February (%)	Mean movement reduction in March (%)	Mean movement reduction in April (%)
Atlanta			
Driving	13·57 (17·36)	-12·63 (28·73)	-37·80 (10·79)
Transit	-5·25 (10·70)	-31·55 (23·27)	-57·72 (3·92)
Walking	15·22 (32·40)	-15·40 (31·79)	-39·33 (9·71)
Auckland			
Driving	8·63 (16·69)	-27·04 (37·31)	-80·27 (11·19)
Transit	15·86 (9·54)	-34·39 (39·63)	-88·83 (3·70)
Walking	16·41 (13·55)	-25·00 (33·76)	-71·87 (7·06)

Barcelona			
Driving	18·15 (12·83)	-44·91 (50·72)	-85·04 (4·22)
Transit	63·81 (58·26)	4·86 (113·65)	-88·10 (2·19)
Walking	27·69 (22·18)	-43·21 (61·99)	-92·93 (2·53)
Buenos Aires			
Driving	17·15 (20·75)	-28·74 (55·35)	-79·96 (6·23)
Walking	10·44 (20·63)	-35·41 (56·67)	-89·06 (2·60)
Casablanca			
Driving	14·99 (10·18)	-37·21 (42·81)	-79·93 (3·17)
Walking	20·19 (13·42)	-37·09 (44·46)	-79·32 (2·76)
Helsinki			
Driving	2·34 (6·81)	-23·41 (18·76)	-26·84 (9·09)
Transit	8·15 (7·58)	-34·00 (30·80)	-61·27 (4·60)
Walking	5·09 (14·00)	-27·02 (21·03)	-31·01 (11·34)
Hong Kong			
Driving	-31·35 (5·91)	-36·98 (8·17)	-45·51 (4·66)
Walking	-49·50 (5·43)	-47·73 (7·80)	-53·24 (5·15)
Johannesburg			
Driving	11·94 (13·55)	-21·18 (37·00)	-81·23 (4·19)
Walking	5·37 (12·13)	-26·63 (30·96)	-75·86 (4·98)
London			
Driving	14·61 (8·95)	-26·71 (33·24)	-67·16 (3·97)
Transit	17·76 (10·44)	-38·02 (40·43)	-86·27 (1·02)
Walking	28·03 (22·52)	-30·33 (43·42)	-74·34 (3·24)
Mumbai			
Driving	11·14 (10·01)	-39·81 (36·54)	-87·52 (1·21)
Walking	5·10 (9·35)	-43·04 (33·35)	-85·30 (1·16)
New Orleans			
Driving	-12·22 (29·40)	-49·04 (24·22)	-69·36 (5·20)
Transit	1·22 (19·99)	-39·72 (38·74)	-80·26 (2·08)
Walking	-36·89 (43·88)	-74·85 (20·32)	-93·15 (0·99)

New York City			
Driving	8·47 (12·11)	-26·78 (30·97)	-54·87 (6·05)
Transit	1·30 (10·35)	-48·74 (36·14)	-86·43 (1·06)
Walking	13·98 (18·64)	-35·91 (40·37)	-74·62 (3·27)
Paris			
Driving	-15·30 (7·53)	-57·52 (29·92)	-82·96 (3·18)
Transit	11·26 (9·67)	-49·32 (44·37)	-89·61 (1·57)
Walking	-17·49 (13·88)	-63·27 (30·45)	-90·38 (1·04)
Rio de Janeiro			
Driving	21·90 (25·42)	-32·52 (34·39)	-62·85 (3·91)
Transit	10·05 (18·67)	-41·30 (42·56)	-83·96 (2·60)
Walking	40·81 (66·41)	-36·00 (41·14)	-75·72 (3·00)
Riyadh			
Driving	3·35 (12·23)	-27·23 (28·05)	-60·95 (5·21)
Walking	0·96 (10·36)	-23·63 (22·90)	-49·10 (5·14)
Rome			
Driving	14·61 (13·16)	-66·72 (30·74)	-84·05 (2·92)
Transit	16·88 (14·80)	-76·37 (28·46)	-93·90 (0·98)
Walking	33·39 (26·30)	-73·58 (29·37)	-91·80 (1·51)
Santiago de Chile			
Driving	-10·11 (14·55)	-30·66 (38·88)	-61·80 (10·29)
Walking	-19·23 (20·88)	-38·39 (44·75)	-79·04 (5·74)
Singapore			
Driving	-17·08 (6·14)	-25·49 (8·80)	-57·36 (10·73)
Transit	-28·94 (6·33)	-38·11 (11·06)	-80·91 (10·89)
Walking	-25·02 (9·61)	-39·65 (10·64)	-67·32 (8·53)
Stockholm			
Driving	8·92 (8·38)	-13·94 (15·02)	-12·80 (8·76)
Transit	12·06 (6·89)	-28·34 (25·12)	-46·68 (4·72)
Walking	16·85 (16·80)	-20·92 (26·14)	-32·07 (8·92)
Sydney			

Driving	12·58 (11·26)	-15·57 (23·06)	-44·67 (11·02)
Transit	8·99 (11·91)	-32·81 (33·74)	-78·12 (2·85)
Walking	10·52 (18·35)	-27·97 (29·14)	-60·18 (4·81)
Tel Aviv			
Driving	3·76 (10·27)	-38·86 (32·72)	-62·06 (11·75)
Walking	7·83 (16·65)	-33·76 (44·03)	-66·59 (10·65)
Toronto			
Driving	5·63 (14·03)	-29·53 (30·79)	-57·78 (6·75)
Transit	-5·12 (10·32)	-45·18 (33·80)	-82·68 (1·64)
Walking	10·56 (18·65)	-27·60 (36·64)	-62·42 (5·19)

**Transit data not available for these cities*

Date are n (%), or mean (SD).

Supplementary Figures: uploaded separately as per MJA instructions to authors

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sFigure 1: North American cities

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sFigure 2: South American cities

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sFigure 3: Western European cities

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sFigure 4: Nordic cities

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sFigure 5: Southern European cities

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sFigure 6: Asian cities

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sFigure 7: Oceanic cities

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sFigure 8: Middle Eastern cities

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sFigure 9: African cities

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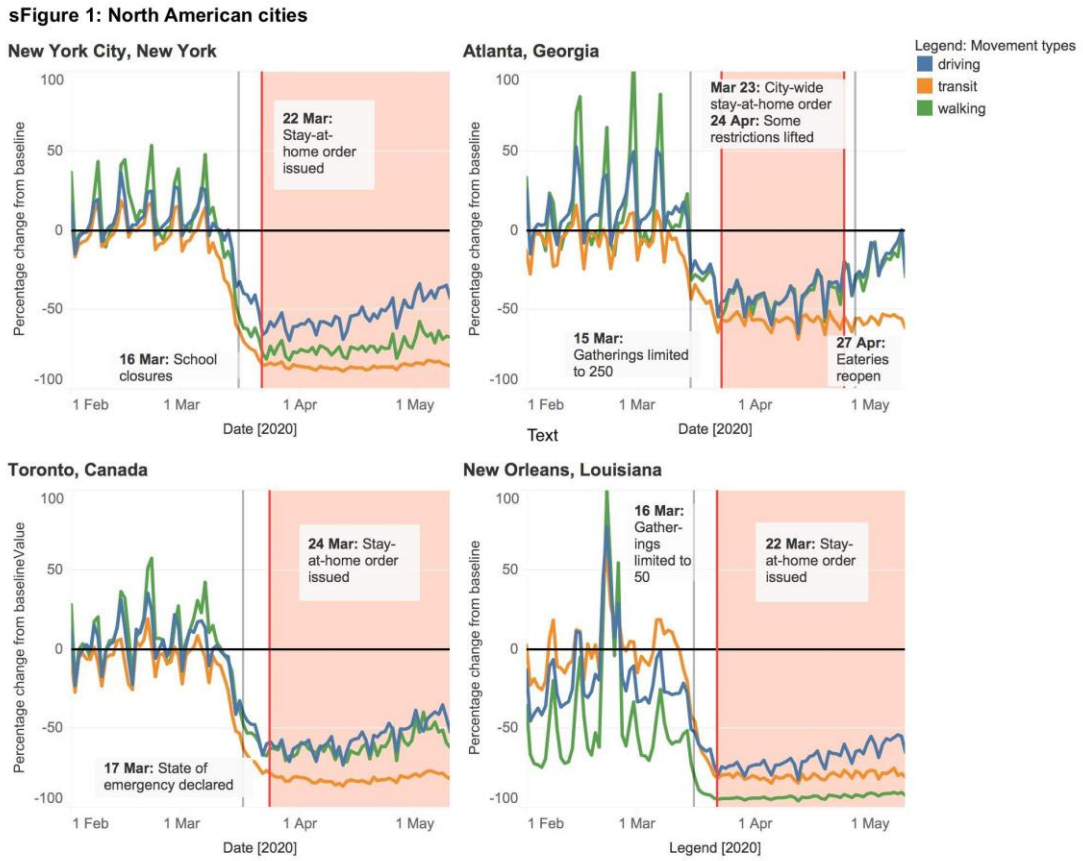
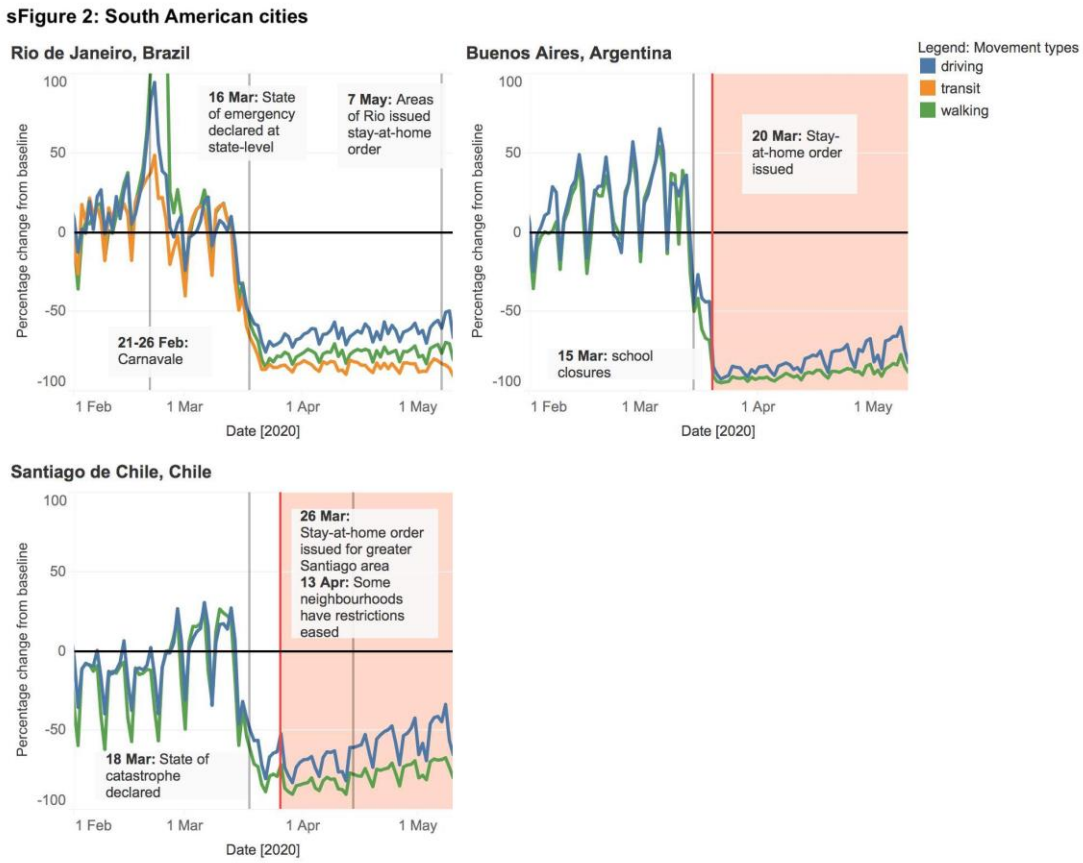


sFigure 1: North American cities



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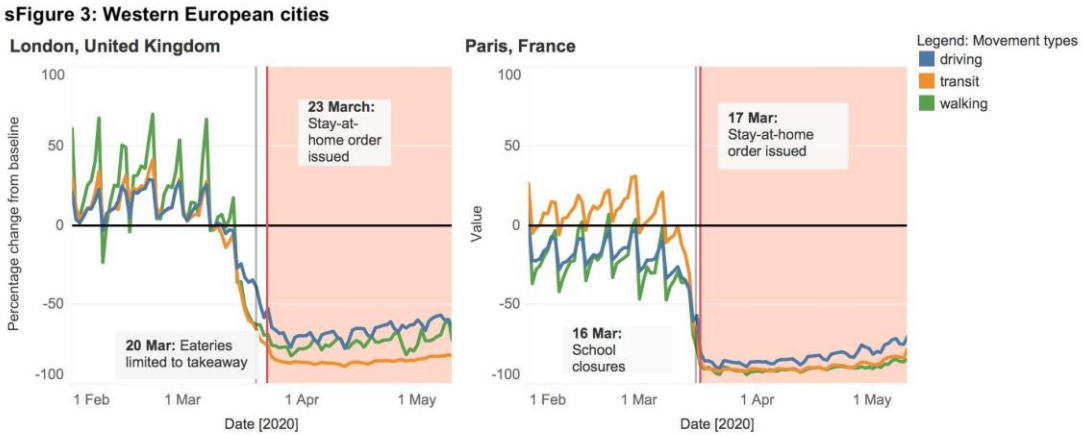
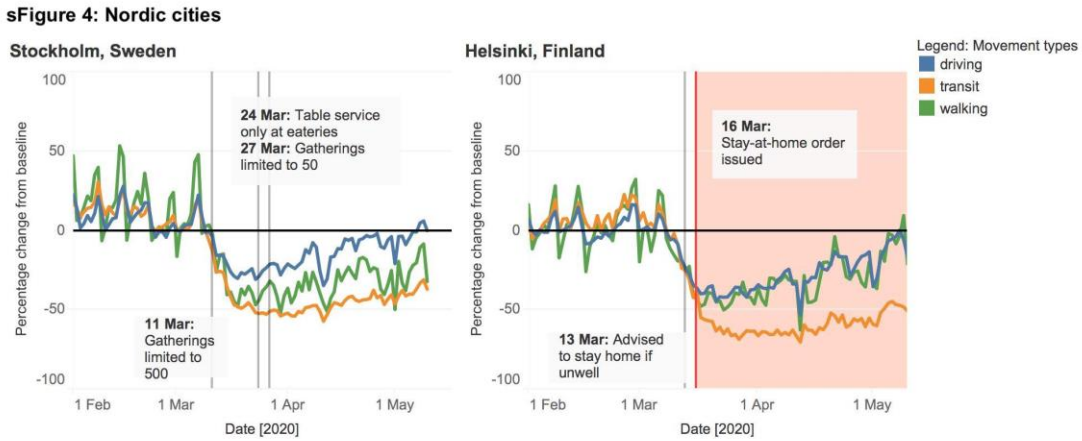


sFigure 3: Western European cities



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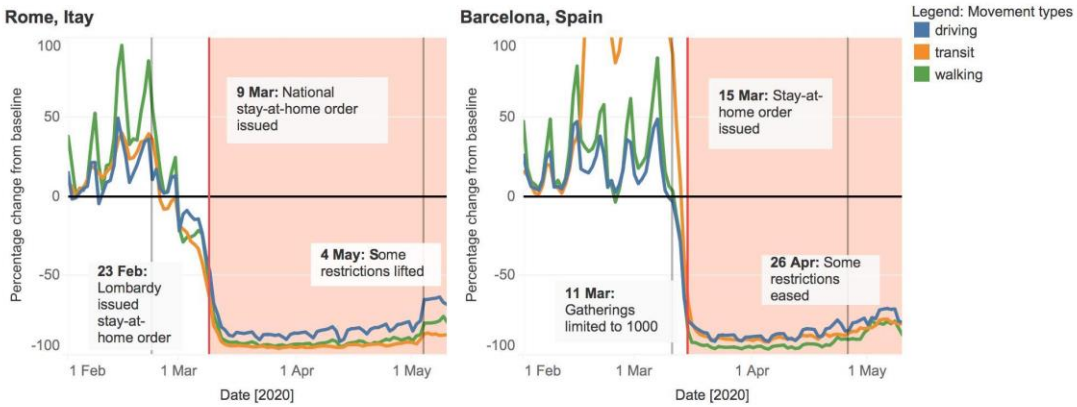
sFigure 4: Nordic cities

sFigure 5: Southern European cities



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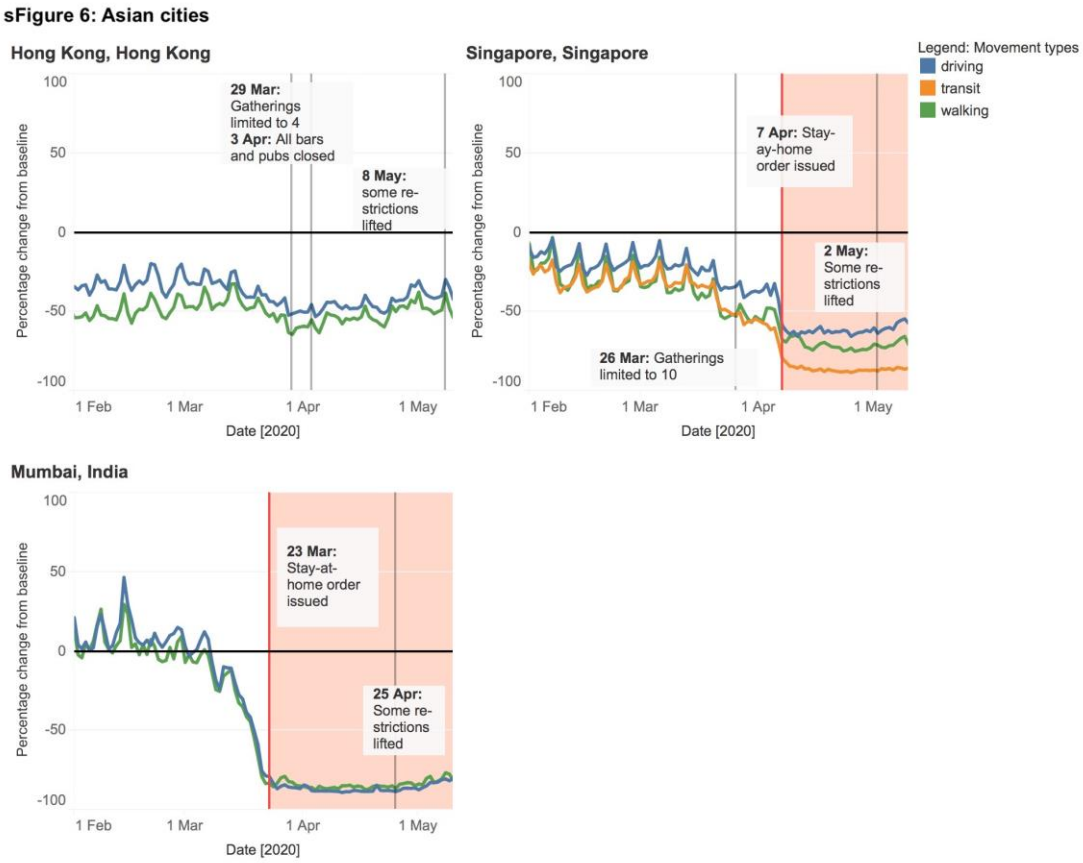
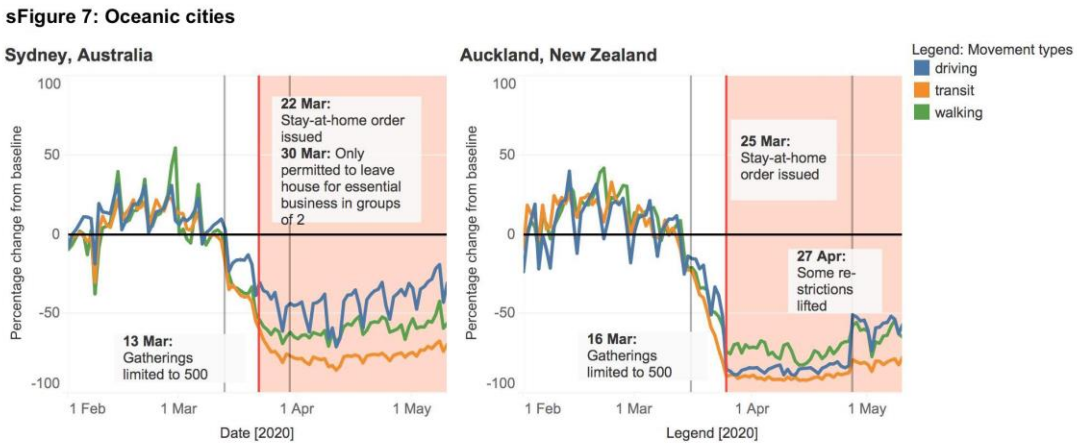
sFigure 5: Souther European cities



sFigure 6: Asian cities



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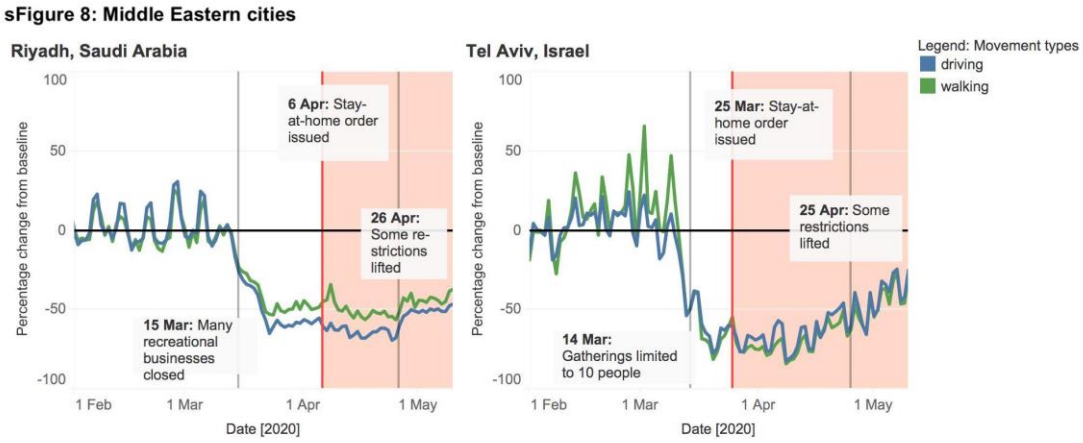
sFigure 7: Oceanic cities



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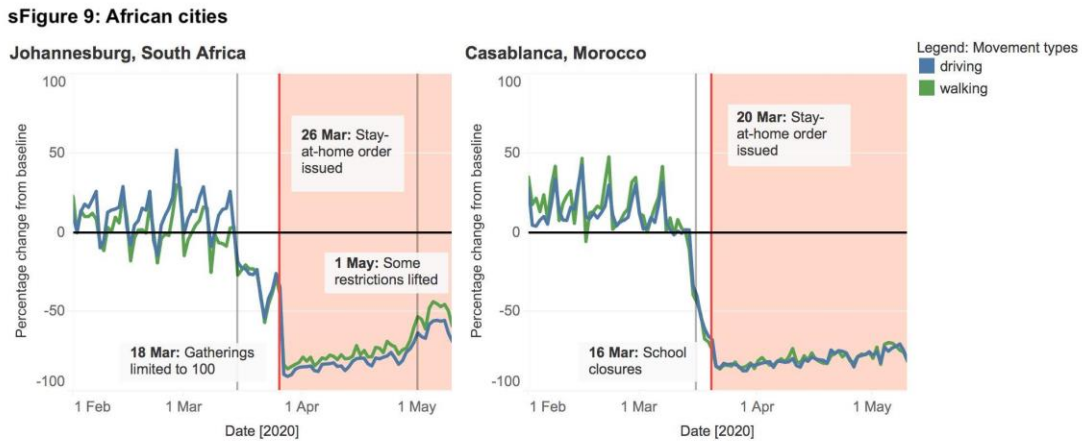
sFigure 8: Middle Eastern cities



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sFigure 9: African cities