Citizen mobility and the growth of infections during the COVID-19 pandemic with the effects of government restrictions in Western Europe

Mohd Sarim, Qunshan Zhao*, Nick Bailey

Urban Big Data Centre, School of Social and Political Sciences, University of Glasgow, Glasgow, G12 8RZ, UK

Email:

Mohd Sarim: sarim91@gmail.com

Qunshan Zhao: Qunshan.Zhao@glasgow.ac.uk

Nick Bailey: Nick.Bailey@glasgow.ac.uk

***Corresponding Author: Qunshan.Zhao@glasgow.ac.uk**

Abstract: Mobility restrictions have been imposed by many countries in order to curb the spread the novel coronavirus disease. These vary in overall severity but also in the details of which kinds of activity and hence mobility has been permitted or restricted. This study uses the Oxford COVID-19 Government Response Tracker to measure the severity of restrictions on mobility in eight Western European countries but adds additional understanding on the nature of restrictions by combining this with mobility data from Google on different activities. The countries were classified into three categories based on the observed changes in mobility patterns, reflecting differences in the approach rather than severity. The paper then assesses the relationships between mobility patterns and the spread of the virus by looking at the growth rate ratio. The time lag for the highest correlation was observed to be in the range of 14-20 days in most cases. In some countries, however, there is no correlation between mobility in parks and spread of disease, suggesting this activity is relatively safe with appropriate social distancing. These findings support the use of social distancing measures in order to limit the spread of COVID-19 and could also be helpful in case of any future outbreaks of similar infectious diseases.

Keywords: SARS-CoV-2, growth of infections, Google community mobility reports, government restrictions

1. Introduction

The Coronavirus (COVID-19) pandemic has led to a massive disruption in the daily lives of people all around the world. The novel coronavirus (SARS-CoV-2) disease, also known as COVID-19 was first identified in December 2019 in the city of Wuhan, which is a part of the Hubei province in China. Due to a high frequency of travel and its highly infectious nature, it quickly spread across the globe. On January 30th, 2021, the World Health Organization officially declared the coronavirus outbreak as a public health emergency of international concern. It was later declared a global pandemic, owing to a rapid rise in the number of cases and deaths across multiple countries, including many in Western Europe which is the focus in this research. As of August 10th, 2020, over 19.7 million confirmed cases and more than 720 thousand deaths have been reported (W.H.O., 2020).

Since there are currently no effective vaccines for the disease, the primary strategies to mitigate its rapid spread have been to encourage greater personal hygiene and more social distancing. For the latter, several countries placed restrictions on the movement of people outside the home and restricted certain kinds of social or economic activity. These measures, also referred to as 'lockdowns' in the more extreme cases, have varied in terms of severity or stringency, dependent on the extent of the disease outbreak as well as the political choice of the governments. They have also varied in the details of which activities were permitted at any time: which kinds of social activity were permitted or whether people were required to work from home, for example. Governments have also been concerned to keep social distancing measures to the minimum necessary, due to concerns about the social and economic impacts, and citizen compliance. To support compliance, it is important to study the effectiveness of these measures in limiting the transmission of the disease.

This research examines the mobility patterns across eight major Western European countries and their variation with the governmental responses. It seeks to identify different approaches to restrictions and to understand which kinds of restriction were most important for limiting the transmission of the disease. Mobility data is obtained from the COVID-19 Google Mobility Reports (Google, 2020), whereas data on governmental responses and the number of cases is derived from the Oxford COVID-19 Government Response Tracker (Oxford: Blavatnik School of Government, 2020).

2. Literature Review

Several studies have analyzed the mobility patterns after the start of the pandemic. Saha et al. (2020) used Google's Community Mobility Reports for India to analyze the impact of lockdown on community mobility. Exploratory analysis was used to plot state-wise changes in mobility at different categories of places. The data was divided into two timeframes: pre-lockdown and post-lockdown, and plots were generated showing the mobility changes for these timeframes. Additionally, spatial changes in mobility were shown for different times using maps. Warren and Skillman (2020) used anonymized data on mobile phone locations in the US to measure the changes in mobility. The location data for a designated time period before the lockdown was used to set up a baseline value for mobility. Then, the daily location data was used to calculate the percentage change in mobility for that day. These changes showed a dramatic drop in mobility across the US.

It is also important to understand the relationship between the transmission of COVID-19 and mobility to evaluate the impacts of the mobility restrictions. Most early studies in this regard focused on China. Kraemer et al. (2020) used real-time mobility data from Baidu Inc., and case data with travel history in order to determine the role of travel in the transmission of the virus. They used a generalized linear model to predict the daily case counts in other provinces, considering the mobility patterns in and outside Wuhan. The model predicted the number of cases with high accuracy. This work also helped to ascertain the effectiveness of the control measures in limiting the spread. A similar study was done by Zhao et al. (2020) that used correlation analysis to quantify the relationship between travel behavior and the number of transmissions to other areas. It found a positive correlation between the passenger traffic and the number of confirmed cases in 10 cities around Wuhan. Vinceti et al. (2020) used anonymized data from mobile phone movements to track citizen mobility in the most affected provinces of Italy. They modelled the daily trends of mobility and the number of cases using linear regression. The results showed a positive association of governmental interventions with the number of cases and the reduction in mobility.

Growth rate (cases per day) has been used to evaluate the impact of changes in mobility on the spread of the virus. Utsunomiya et al. (2020) created a framework to enable real-time analysis of the growth rate and growth acceleration using the moving regression technique and a hidden Markov model. The results showed that the growth acceleration started to decrease within a week of the restrictions being put in place. It also predicted a constant but small growth after 6 weeks. Badr et al. (2020) calculated the correlation between mobility and the growth rate of infections. Anonymized cell phone data was used to create a social distancing metric (mobility ratio), while the daily number of new cases were used to calculate the Growth Ratio. Correlations were then computed between these two metrics for different time lag intervals. The results showed that the correlation was highest for a time lag of 9-12 days, which is consistent with the incubation time of COVID-19.

Most studies have focused on a single country, with only a few (Seibold et al., 2020; Utsunomiya et al., 2020) expanding their analysis across multiple countries. However, only a few studies have used the Google Mobility Reports to compare the impacts of restrictions across various countries (Zhu et al., 2020), with no study focusing on different Western European countries with serious COVID-19 infection.

3. Data

3.1 Mobility levels

The COVID-19 Community Mobility dataset (Google, 2020) published by Google was used to assess the mobility levels. This data tracks the changes in mobility at six different categories of places using the location of mobile phones. Data is collected from devices that have ‘Location History’ setting turned on voluntarily by Google users. The mobility changes are compared to a baseline value for each day of the week. These baseline values are calculated by using the median mobility for the given day over a 5-weeks period over January and February 2020. Different days of the week have different baseline values, which means that comparison of day-to-day changes in mobility is not suitable. Another important point to note is the difference in the calculation of mobility changes at residences and all other places. The residential changes are measured as a change in the average duration of time (in hours) spent at home. Since a day only has 24 hours, the percentage changes are limited in this case. On the other hand, the changes in all the other categories are measured in terms of the number of visitors, which means the changes are not bounded. The different categories of places are:

- Residential – areas earmarked as residential.
- Parks – areas officially designated as parks, such as National parks, castles and public gardens.
- Grocery and Pharmacy – places involving essential trips, like groceries and pharmacies.
- Retail and recreation – Shopping centers, restaurants, theatres and other places of recreational activities.
- Transit Stations – Bus, train and subway stations, as well as taxi stands and car rental agencies.
- Workplaces – locations marked as workplaces.

The values of transit and retail mobility were found to be highly correlated with the workplace mobility. Therefore, four categories of places are selected for this analysis: Residential, Parks, Grocery and Pharmacy, and Workplaces.

3.2 Restrictions and Number of cases

The restrictions on mobility are assessed using the Oxford COVID-19 Government Response Tracker (Oxford: Blavatnik School of Government, 2020). The governmental responses are measured through 17 indicators that correspond to various policy measures. Eight indicators identify the closure and containment policies, such as the closures of schools and workplaces. Five indicators measure healthcare responses such as testing policies and emergency investments, while the other four indicators correspond to the economic policies such as income support and fiscal measures. The Stringency Index, which is an average of eight closure and containment policy indicators and one healthcare measure, is used to quantify the responses of the governments to the pandemic (Hale et al., 2020). Using the Stringency Index has the advantage of having a graduated scale to model the restrictions, instead of a binary variable that denotes the presence of a lockdown. The Stringency Index ranges from 0 (no restrictions) to 100 (most stringent restrictions). In order to better visualize the mobility trends with introduction of restrictions, the Stringency Index is converted to the Freedom of Association Index, which is calculated as:

Freedom of Association Index = (100 – Stringency Index)

The OxCGRT dataset also tracks the total number of confirmed cases and deaths due to COVID-19. These cumulative values are used to calculate the daily rise in the number of cases.

4. Lockdown Level Classification based on Mobility Patterns

Plots are created for each country using the mobility changes at the selected categories of places (Residential, Parks, Grocery and Pharmacy, Workplaces) as well as the freedom of association index (All the analysis source codes are available at https://github.com/mdsarim/COVID-19). As the data captures weekly changes, the x-axis is divided into weeks to better understand the patterns of mobility. For each country, a dramatic change in mobility is observed around the dates when there is a sharp decline in the freedom of association index ('lockdown date'). However, the freedom of association started to decline before the lockdown date. This was found to be the result of preventive measures taken before a full lockdown was put in place. These measures included closure of educational institutions, ban on gatherings and in some cases, restrictions on movement of people.

For all countries, some days witnessed unusual decreases in workplace mobility, and corresponding increases in residential mobility. Further examinations revealed those days to be public holidays. Each country witnessed a significant rise in residential mobility after the lockdown. There was a weekly pattern where the weekends saw lower changes than weekdays, which is understandable as workers tend to remain at home on weekends. The mobility changes for other categories, however, were not similar for each country. Based on the values for different categories, three distinct patterns were observed for the eight Western European countries:

4.1 Strict - France, Italy and Spain

The mobility patterns in France, Italy and Spain were found to be similar (Figure 1, 2 and 3). Following the lockdown, there was a sharp decline in mobility at workplaces, parks and groceries in these countries. The freedom of association was the lowest (amongst the eight countries considered), suggesting the imposition of the strictest measures to curb the spread of the virus. This also pointed to a high compliance among the people. Such strict measures were deemed necessary as these were some of the worst-affected countries in terms of infections and deaths.

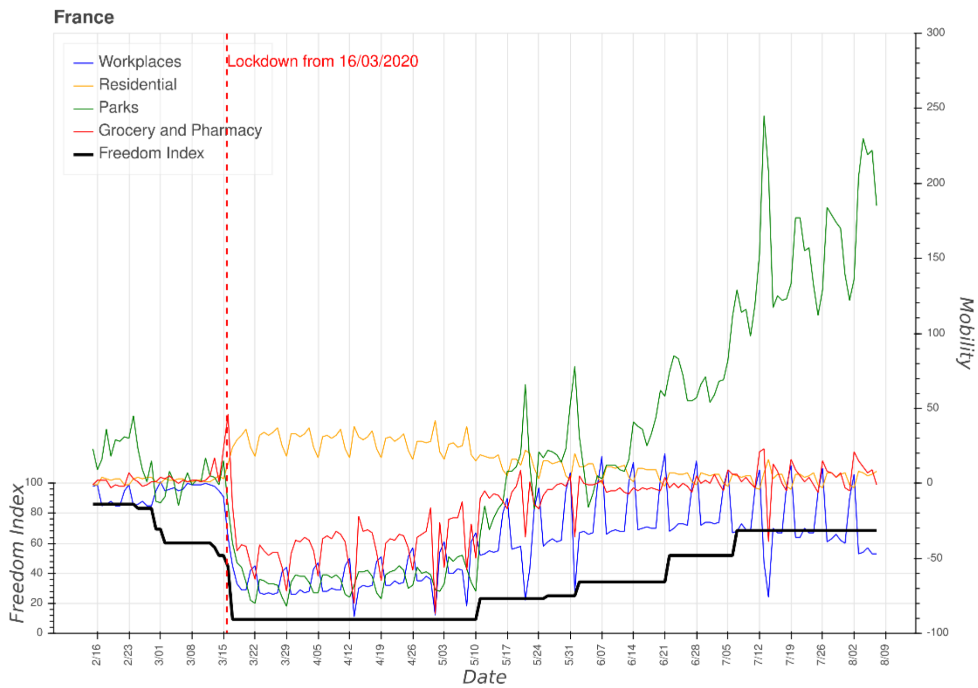

Figure 1. Mobility and freedom of association in France.

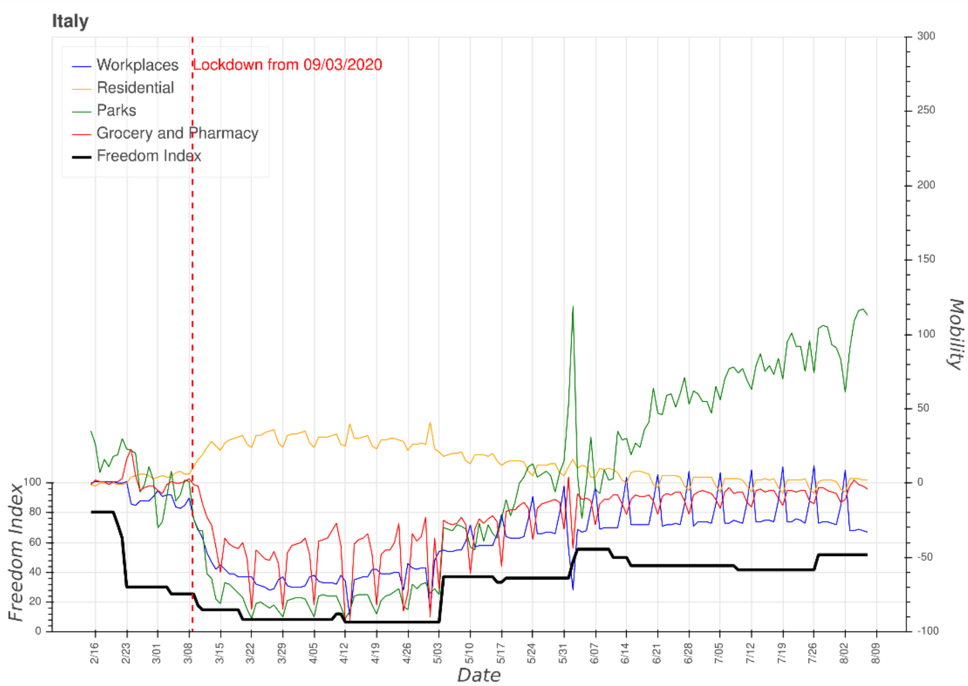

Figure 2. Mobility and freedom of association in Italy.

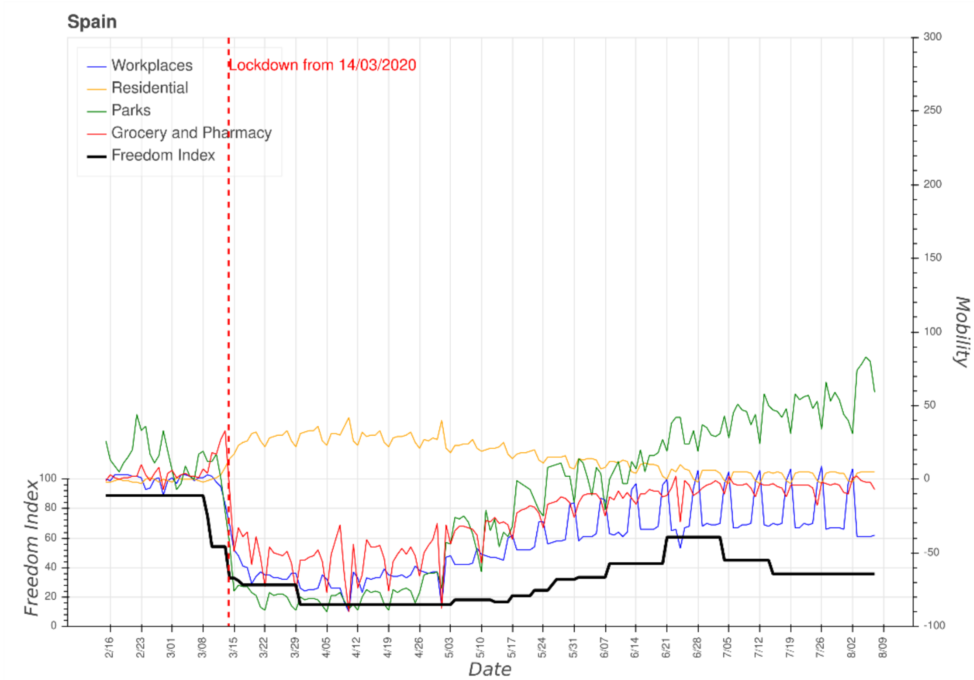

Figure 3. Mobility and freedom of association in Spain.

Mobility changes in Italy started when lockdown measures were imposed in the Italian provinces of Lodi and Padua on February 21st. Educational institutions and workplaces were closed, and public gatherings were banned (Metro, 2020). France and Spain also initiated similar restrictions in early March. This led to a decline in the freedom of association even before the official lockdown date, as seen in the plots. Later, due to a continuous rise in the number of infections, country-wide lockdown measures were imposed in Italy (March 9th), Spain (March 14th) and France (March 16th). All non-essential businesses were ordered to close, and workers were encouraged to work from home if possible. Strict stay-at-home orders meant that people could go out only for essential supplies and in emergencies. This resulted in a decline of 60-70% in workplace mobility. Due to the closure of parks and public spaces, mobility for parks also saw a sharp decline (Reuters, 2020), with the weekdays witnessing a fall of at least 60%. The weekends saw even more decline, suggesting a higher baseline value at parks during weekends. Mobility at groceries and pharmacies also decreased significantly post lockdown, with a change of 40% compared to the baseline levels until late April.

Lockdown measures were gradually eased since May, with workplaces and parks allowed to open (Aljazeera, 2020; The Guardian, 2020a). This resulted in a significant increase in grocery and parks' mobility patterns, and a decrease in time spent at homes. While the mobility at groceries and homes hit pre-lockdown levels, more and more people were visiting parks. In case of workplaces, the mobility increased with the easing of restrictions, but did not reach pre-lockdown levels. Amid fears of a second wave of infections, Spain and Italy reintroduced some restrictions, but these did not have much impact on mobility.

4.2 Intermediate - Belgium and the UK

The freedom of association values for Belgium and the UK were close to those of the first group (scores around 20-22/100 as compared to 6-16/100, Figure 4 and 5). While they witnessed a steep decline in workplace mobility, they saw relatively small decrease in that of parks and groceries post-lockdown.

Belgium banned public gatherings and closed schools, cafes and other public places from March 12th. The UK government also advised against non-essential travel and public gatherings on March 16th, and ordered the closure of schools, restaurants and pubs from March 20th. These are also reflected in the freedom of association, which declined around the same time. Following a rise in cases, a country-wide lockdown was imposed from March 17th in Belgium, and from March 23rd in the UK. Stay-at-home orders were put in place, along with the closure of all non-essential businesses and shops (Belgian Federal Government, 2020). The UK also introduced the 'Coronavirus Act 2020', which assigned emergency powers to the government for tackling the pandemic (Cabinet Office, 2020; UK Legislations, 2020). As a result, workplace mobility decreased by more than 60%. These countries did not close parks and allowed citizens to go out for physical activities such as running and cycling. However, such visits were limited by visiting frequency. As a result, the mobility at parks initially remained below pre-lockdown levels.

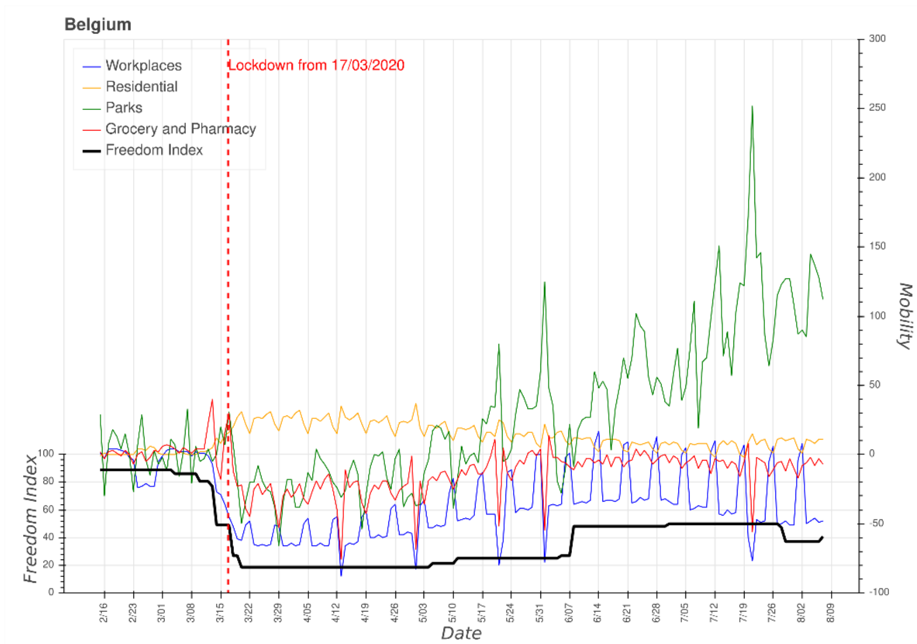

Figure 4. Mobility and freedom of association in Belgium.

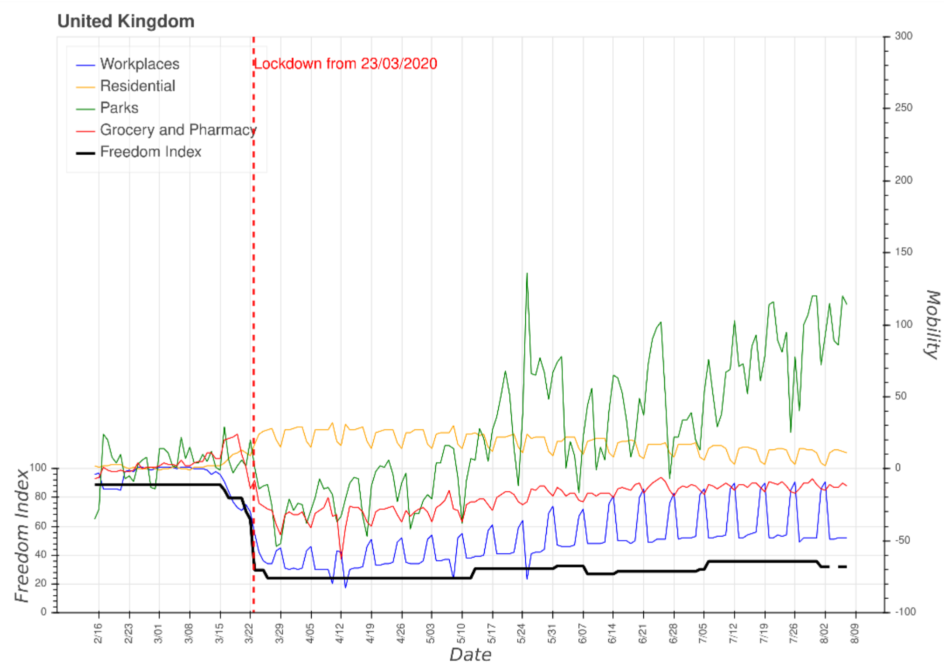

Figure 5. Mobility and freedom of association in the UK.

Both Belgium and the UK started easing the lockdown restrictions in early May (The Guardian, 2020b). This resulted in a gradual increase in mobility. However, the changes were different for each category. While mobility at groceries and workplaces increased slowly, there was a huge rise in park visits. This could be due to the lifting of restrictions on the number of park visits, as well as good weather conditions. One important point to note is that despite easing of restrictions, the workplace mobility in Belgium peaked in June and started going down long before some restrictions were imposed again.

4.3 Flexible - Germany, Switzerland and the Netherlands

Germany, Switzerland, and the Netherlands witnessed similar values of freedom of association as Belgium and the UK (Figure 6, 7, and 8). However, the mobility changes were smaller at groceries and workplaces, with a huge rise in park visits.

Preventive measures were initiated in Germany and Switzerland towards the end of February, with closure of schools and cancellation of public events and gatherings (The Federal Council, 2020). Similar steps were taken by the Netherlands in early March. Consequently, the freedom of association also started to decrease. The German states of Bavaria and Saarland were the first to introduce lockdown from March 20th (The Independent, 2020), which was extended to other parts of the country on March 22nd. Although there was no official lockdown in Switzerland, schools and colleges were ordered to close from March 13th. Bars, restaurants and non-essential shops were also closed from March 16th. The Netherlands also enforced lockdown measures from March 23rd. As a result, mobility at workplaces decreased significantly, though it remained less than 50% (except public holidays). Mobility at groceries only decreased slightly (< 20%)

after lockdown, and increase in residential mobility was also small relative to the other categories.

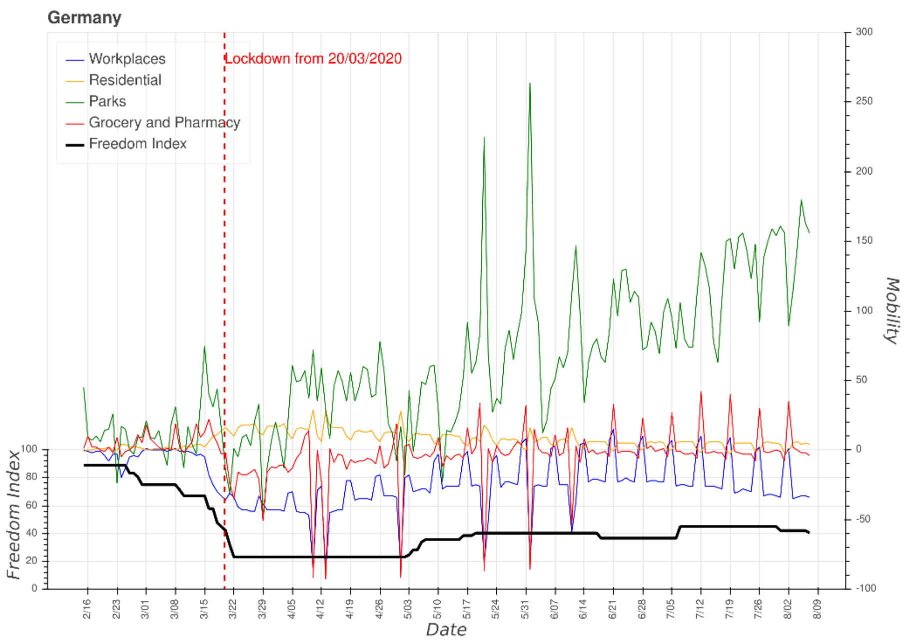

Figure 6. Mobility and freedom of association in Germany.

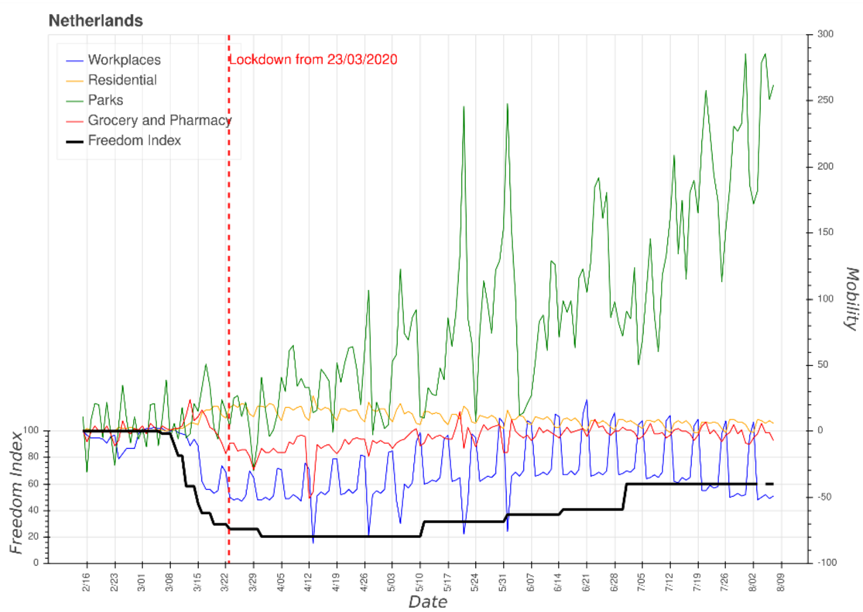

Figure 7. Mobility and freedom of association in the Netherlands.

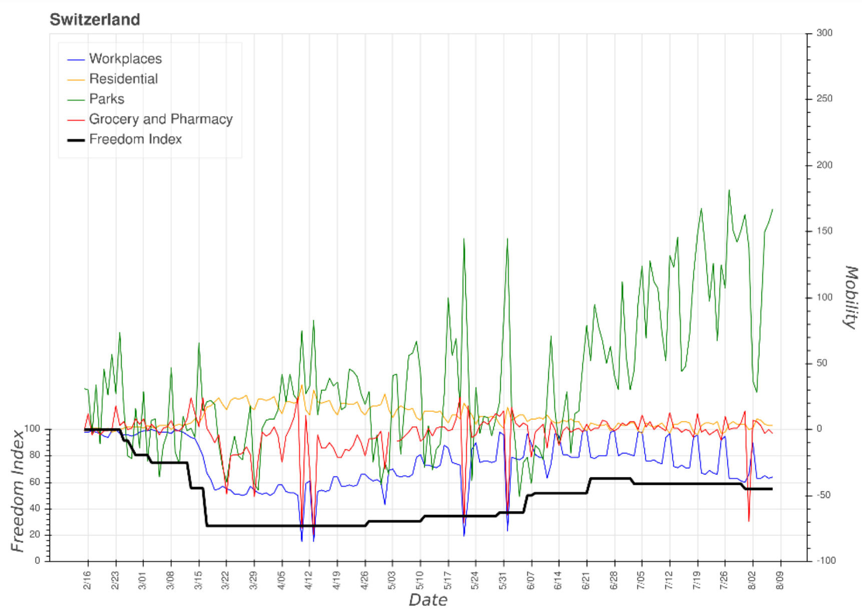

Figure 8. Mobility and freedom of association in Switzerland.

A distinct feature of this category was the mobility at parks. These countries did not restrict visits to parks, which led to a general increase in mobility. Notably, the baseline values used were from January, when the weather is generally cold. Nevertheless, this continuous upward trend is not present for any of the other groups of countries, which suggests that lockdown did not reduce the number of visitors in parks. In Germany and Switzerland, there was a dip at the end of March and mid-May. On further examination, these days were found to have bad weather and low temperatures.

Since the end of April, these countries also started easing restrictions. This resulted in an increase in workplace mobility, and a corresponding decrease in time spent at home. The grocery mobility crept back to pre-lockdown levels, while there was a huge increase in park visits. Like Belgium, these countries also saw a peak in workplace mobility in June, and a downward trend afterwards.

5. Mobility Correlation Analysis

5.1 Correlation between Freedom of Association and Mobility

To further understand the relationship between the freedom of association and the mobility at various places, correlation coefficients were calculated between the freedom of association index and each category (Table 1). These correlation coefficient values are consistent with the earlier classification. Residential mobility for each country shows a strong negative correlation with the freedom of association, since the lockdown required people to stay at home. France, Italy and Spain show strong correlation for all other categories as well, which means that restrictions were imposed and followed at all places. As mentioned earlier, parks in these countries were closed during the lockdown, which caused a large decrease in mobility. In case of Belgium and the UK, all categories except parks were found to be highly correlated with the freedom of association. The mobility at groceries was highly correlated with the freedom of association except in the third group of countries (Germany, Switzerland and the Netherlands).

Table 1. Correlation coefficients between freedom of association and mobility.

Country	Residential	Parks	Grocery	Workplaces
France	-0.829**	0.739**	0.741**	0.678**
Italy	-0.828**	0.771**	0.699**	0.769**
Spain	-0.777**	0.571**	0.714**	0.802**
Belgium	-0.803**	0.185	0.593**	0.680**
United Kingdom	-0.783**	-0.116	0.790**	0.821**
Germany	-0.636**	-0.146	0.287**	0.558**
Netherlands	-0.754**	-0.015	0.411**	0.507**
Switzerland	-0.793**	0.171*	0.328**	0.716**

* $p<0.05$ ** $p<0.01$

5.2 Correlation between Growth Rate Ratio and Mobility Change

The OxCGRT dataset tracks the cumulative number of confirmed cases for each country. The daily number of cases on a particular day was calculated by subtracting the number of cases on the previous day from the number of cases on that day. To quantify the growth of infections, a measure called the Growth Rate Ratio (GRR) was used. The GRR, defined by Badr et al. (2020) in their study, is the ratio of the logarithmic change of cases over previous 3 days to that over the previous week. The daily cases were used to calculate the GRR using the following equation:

$$GRit= \log t-2tCit3 \log t-6tCit7\#1$$

where $GRit$ is the GRR and $Cit$is the number of cases in country i on day t. A GRR greater than 1 suggests a relative increase in growth rate compared to the previous week, with a decrease denoted by a value of less than 1.

Several studies have found the median incubation time of COVID-19 to be around 5 days, with 95% people showing symptoms within 12.5 days (Lauer et al., 2020; Li et al., 2020). As the incubation time differs in each case, accounting for the delay in reporting, 14 days has been considered the maximum incubation time. This has also been used by countries as the quarantine period for anyone who has been at risk of infection. A time lag is expected between the change in mobility and the subsequent change in growth rate, since mobility changes are not expected to affect the growth rate immediately. Correlation coefficients were calculated between the mobility changes at different places and the 7 days rolling average of GRR values using different time lags. The statistically significant results for all countries are shown in Figure 9 ($p<0.05$).

The mobility values at each category of places were used to calculate correlation coefficients with the GRR. For Spain and Italy, the correlations peaked between a lag of 14 and 18 days, with all values above 0.6. Grocery mobility showed the weakest correlation with GRR, with all other places showing values above 0.9 during the peak. After 20 days the correlations declined sharply, which could be due to a decrease in the number of reported cases while mobility remaining stable. In case of France, the correlations started peaking around a lag of 18 days, and then started declining after 22 days. The GRR in Germany, Switzerland and the Netherlands showed high correlation with the workplace and residential mobility, and only a weak correlation with mobility at grocery and pharmacy. The mobility at parks showed a negative correlation for most of the statistically significant correlation values. The coefficients in case of Belgium and the UK also followed largely the same patterns, with the notable difference being with parks, where the correlation was stronger than Germany, Netherlands, and Switzerland but weaker than Italy, France, and Spain. A notable observation is that there is a different time lag value for which the country achieves a peak value of correlation. This suggests that there are some-country-specific factors in play that have influenced the rate of growth of new infections. Nevertheless, there is satisfactory evidence to support the role of social distancing in reducing the spread of the virus.

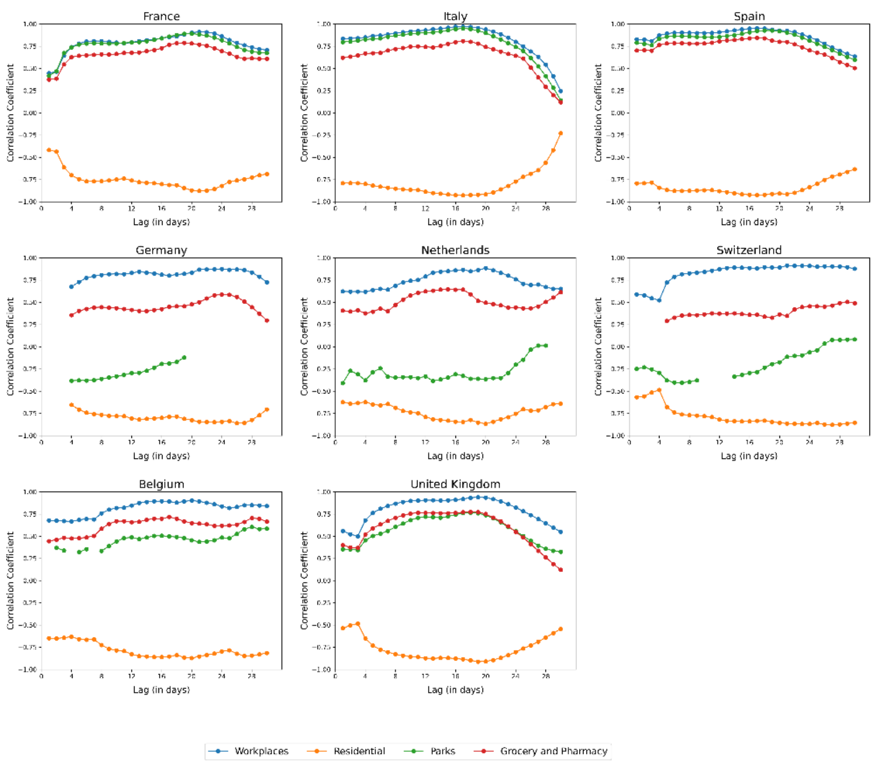

Figure 9. Correlation Coefficients between GRR and mobility change for different time lags.

6. Discussion and Conclusions

This research used aggregated mobility data provided by Google to monitor the changes in mobility in a number of major Western European countries. The mobility data was compared to the government responses, which were captured by the Oxford COVID-19 Government Response Tracker (OxCGRT). On the basis of mobility patterns, the eight countries were divided into three lockdown categories (strict, intermediate, and flexible). Furthermore, the daily number of cases was used to calculate the GRR for each country. Correlation coefficients were then calculated between GRR and the mobility changes, with different time lags. The results show that the GRR in highly correlated with the decrease in workplace and residential mobility for a time lag window, which suggests that the mobility restrictions could have been effective in decreasing the number of infections.

Based on the analysis of human mobility, freedom of association index, and COVID-19 growth rate ratio, the obvious conclusion is that the strict restriction of mobility such as working from home order is extremely important to limit the spread of COVID-19 infectious. Further, the limitation of mobility will not result in an immediate COVID-19 growth rate decline due to the virus incubation time. Thus, it is very important to impose enough time of lockdown (at least 2 to 3 weeks) to see the control of the virus from mobility restriction. Specifically, doing essential shopping and exercising in the parks with carefully social distancing and usage of face masks is not necessary to increase the growth rate of the virus.

There are a few limitations of this research that need to be discussed. Firstly, discussing the growth rates for different countries presents various challenges. For instance, the testing policies are not the same for each country, which could have effects on the number of reported cases. The level of infection and community spread before the restrictions also varies between countries. Secondly, the relationship between cases and mobility could work both ways. An increase in the number of cases could also result in a decrease in mobility, as people refrain from going out due to rising infections. Finally, there may be other factors such as preventive measures (handwashing and wearing masks) that could also affect the growth rate. The effect of such factors has not been discussed in this analysis.

The use of Google's Community Mobility data as a measure of population mobility also has some limitation. Firstly, the data collection methodology is not clearly explained by Google, and it is not known whether any modelling techniques were used while collecting the data. Secondly, this type of data collection may only be suitable for developed countries. It may not work well for developing countries, where there may be a significantly lower percentage of people who own and use location-enabled smartphones, even with the access to the internet. The results in this analysis would be biased towards people who use smartphones and could be significantly different from the real-world scenario. Lastly, due to the reliance on the 'Location History' feature in the user's phone being turned on, the data might not represent the actual mobility patterns. Therefore, caution should be exercised while using the results derived from this type of data. Additional methods and data validation should be used to further confirm the findings from this analysis.

Acknowledgement

The work was made possible by the ESRC's on-going support for the Urban Big Data Centre (UBDC) [ES/L011921/1 and ES/S007105/1]. The authors would like to thank the anonymous reviewers for their insightful comments and suggestions on an earlier version of this manuscript.

Bibliography

Aljazeera, 2020. Italy leads Europe in easing coronavirus lockdown measures [WWW Document]. URL https://www.aljazeera.com/news/2020/05/italy-leads-europe-easing-coronavirus-lockdown-measures-200504101525868.html (accessed 10.8.20).

Badr, H.S., Du, H., Marshall, M., Dong, E., Squire, M.M., Gardner, L.M., 2020. Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study. The Lancet Infectious Diseases. https://doi.org/10.1016/S1473-3099(20)30553-3

Belgian Federal Government, 2020. Coronavirus: reinforced measures [WWW Document]. URL https://www.belgium.be/en/news/2020/coronavirus_reinforced_measures (accessed 10.8.20).

Cabinet Office, 2020. Staying at home and away from others (social distancing) [WWW Document]. URL https://www.gov.uk/government/publications/full-guidance-on-staying-at-home-and-away-from-others/full-guidance-on-staying-at-home-and-away-from-others (accessed 10.8.20).

Google, 2020. Community Mobility Reports [WWW Document]. URL https://www.google.com/covid19/mobility/ (accessed 10.8.20).

Hale, T., Petherick, A., Phillips, T., Webster, S., 2020. Variation in government responses to COVID-19. Blavatnik school of government working paper.

Kraemer, M.U.G., Yang, C.-H., Gutierrez, B., Wu, C.-H., Klein, B., Pigott, D.M., Covid, O., Hanage, W.P., Brownstein, J.S., Layan, M., Vespignani, A., Tian, H., Dye, C., Pybus, O.G., Scarpino, S.V., 2020. The effect of human mobility and control measures on the COVID-19 epidemic in China 6.

Lauer, S.A., Grantz, K.H., Bi, Q., Jones, F.K., Zheng, Q., Meredith, H.R., Azman, A.S., Reich, N.G., Lessler, J., 2020. The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. Annals of Internal Medicine 172, 577–582. https://doi.org/10.7326/M20-0504

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K.S.M., Lau, E.H.Y., Wong, J.Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., Tu, W., Chen, C., Jin, L., Yang, R., Wang, Q., Zhou, S., Wang, R., Liu, H., Luo, Y., Liu, Y., Shao, G., Li, H., Tao, Z., Yang, Y., Deng, Z., Liu, B., Ma, Z., Zhang, Y., Shi, G., Lam, T.T.Y., Wu, J.T., Gao, G.F., Cowling, B.J., Yang, B., Leung, G.M., Feng, Z., 2020. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia. New England Journal of Medicine 382, 1199–1207. https://doi.org/10.1056/NEJMoa2001316

Metro, 2020. What towns in Italy are on lockdown because of coronavirus? [WWW Document]. URL https://metro.co.uk/2020/02/25/towns-italy-lockdown-coronavirus-12298246/ (accessed 10.8.20).

Oxford: Blavatnik School of Government, 2020. Oxford COVID-19 Government Response Tracker, Blavatnik School of Government [WWW Document]. URL

https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker (accessed 10.8.20).
Reuters, 2020. Italy closes all parks in further tightening of coronavirus lockdown [WWW Document]. URL https://uk.reuters.com/article/uk-health-coronavirus-italy-crackdown/italy-closes-all-parks-in-further-tightening-of-coronavirus-lockdown-idUKKBN21739M (accessed 10.8.20).
Saha, J., Barman, B., Chouhan, P., 2020. Lockdown for COVID-19 and its impact on community mobility in India: An analysis of the COVID-19 Community Mobility Reports, 2020. Children and Youth Services Review 116, 105160. https://doi.org/10.1016/j.childyouth.2020.105160
Seibold, B., Vucetic, Z., Vucetic, S., 2020. Quantitative Relationship between Population Mobility and COVID-19 Growth Rate based on 14 Countries. arXiv:2006.02459 [physics, q-bio].
The Federal Council, 2020. Coronavirus: Federal Council bans large-scale events [WWW Document]. URL https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-78289.html (accessed 10.8.20).
The Guardian, 2020a. France, Italy and Spain prepare to ease coronavirus lockdowns [WWW Document]. URL https://www.theguardian.com/world/2020/apr/26/france-italy-spain-prepare-to-ease-coronavirus-lockdowns (accessed 10.8.20).
The Guardian, 2020b. Point by point: the UK government's plan to leave lockdown [WWW Document]. URL https://www.theguardian.com/politics/2020/may/11/what-is-covered-in-the-uk-governments-lockdown-easing-plan (accessed 10.8.20).
The Independent, 2020. Coronavirus: Germany introduces first lockdown as Bavaria imposes two-week ban on going outside [WWW Document]. URL https://www.independent.co.uk/news/world/europe/coronavirus-germany-update-lockdown-today-bavaria-latest-a9413746.html (accessed 10.8.20).
UK Legislations, 2020. Coronavirus Act 2020 [WWW Document]. URL https://www.legislation.gov.uk/ukpga/2020/7/contents/enacted/data.htm (accessed 10.8.20).
Utsunomiya, Y.T., Utsunomiya, A.T.H., Torrecilha, R.B.P., Paulan, S. de C., Milanesi, M., Garcia, J.F., 2020. Growth Rate and Acceleration Analysis of the COVID-19 Pandemic Reveals the Effect of Public Health Measures in Real Time. Front. Med. 7. https://doi.org/10.3389/fmed.2020.00247
Vinceti, M., Filippini, T., Rothman, K.J., Ferrari, F., Goffi, A., Maffeis, G., Orsini, N., 2020. Lockdown timing and efficacy in controlling COVID-19 using mobile phone tracking. EClinicalMedicine 25, 100457. https://doi.org/10.1016/j.eclinm.2020.100457
Warren, M.S., Skillman, S.W., 2020. Mobility Changes in Response to COVID-19. arXiv:2003.14228 [cs].
W.H.O., 2020. Coronavirus Disease Situation Report-203 [WWW Document]. URL https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports (accessed 10.8.20).
Zhao, S., Zhuang, Z., Cao, P., Ran, J., Gao, D., Lou, Y., Yang, L., Cai, Y., Wang, W., He, D., Wang, M.H., 2020. Quantifying the association between domestic travel and the exportation of novel coronavirus (2019-nCoV) cases from Wuhan, China in 2020: a correlational analysis. J Travel Med 27. https://doi.org/10.1093/jtm/taaa022

Zhu, D., Mishra, S.R., Han, X., Santo, K., 2020. Social distancing in Latin America during the COVID-19 pandemic: an analysis using the Stringency Index and Google Community Mobility Reports. Journal of Travel Medicine taaa125. https://doi.org/10.1093/jtm/taaa125