COVID Alert Application Effectiveness

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Overview

The purpose of this report is to provide as clear a picture as is possible of the impact that the COVID Alert app had on reducing COVID-19 infections and on reducing deaths due to the COVID-19 virus. To conduct this assessment, our team was provided access to raw data reported for COVID Alert app installations and collected from the COVID Alert server. All of these data arrived as aggregate statistics broken down by province and device type; no personally identifiable information was involved in any aspect of this study.

Approach. To provide this assessment, we have selected two separate but complementary approaches. The first approach uses a statistical model to estimate the number of infections averted in Canada, which is combined with the fatality rate to obtain estimates for the number of deaths averted. The model is grounded in both data derived from Canadian and estimates drawn from international sources. The second approach is a comparative study in which the adoption and usage of the COVID Alert app is compared to similar exposure notification apps deployed in other regions of the world.

Limitations and caveats. It is important to underscore the limitations of our findings. Our modeling method is based on a sound approach first proposed by Wymant et al. and applied to the UK exposure notification app. However, because of the level of aggregation in the data provided for this assessment, most of the model's parameters cannot be estimated directly from the data. Our final estimates for the numbers of averted infections and deaths are based on a range of plausible values for these model parameters, which were taken from similar non-Canadian studies. As a result, we are able to offer loose upper and lower-bound estimates but cannot offer any definitive assessment of whether the true numbers are closer to one or the other bound. Further, the most crucial data required to estimate the numbers of averted infections and deaths, the number of daily exposure notifications sent, are not known for the earliest period of app deployment, i.e., October 2020 - February 2021. Thus, the estimates that we have derived from our modelling pertain only to the time period of March to July 2021.

Because raw data on similar apps developed in other countries are not in the public domain, our comparative analysis was limited to statistics harvested from reports. Each report covers different time periods, which are characterized by different waves of infection at different times, making direct comparison of adoption and effectiveness rough at best.

Findings. Our model-based estimate indicates that usage of the COVID Alert app averted between 6,284 and 10,894 infections across the six provinces in Canada where app usage was highest during the March - July 2021 period. This range is equivalent to 1.6%-2.9% of the total recorded infections across the six provinces. Using province-specific fatality rates, we estimate that usage of the app averted between 57 and 101 deaths, again only during the March - July 2021 period. This result is equivalent to 1.6%-2.9% of all recorded COVID-induced fatalities across the six provinces in that time period.

Though nationwide app usage rates were low during the period of assessment, provinces in which there was widespread adoption of the app – notably, Newfoundland and Labrador and Nova Scotia - showed dramatically higher ratios of averted cases and averted deaths. In Newfoundland and Labrador, for example, the upper bound of the number of cases averted was greater than 60% of total recorded cases in the period of analysis. This finding strongly suggests that the COVID Alert app, when adopted at sufficient levels, can be an effective tool for curtailing a pandemic like COVID-19.

Our comparative analysis revealed that the COVID Alert app had one of the lowest adoption levels among similar apps that reported usage. However, actual impact measures were reported for so few apps and so inconsistently that any relative assessment of impact is speculative.

About the authors

Shuo (Mila) Sun is a Ph.D. candidate of Biostatistics at McGill University, advised jointly by Erica Moodie and Johanna Nešlehová. Her research interests generally lie in causal inference, extreme value theory, and quantile regression. She is also interested in applications of statistical methods to environmental science and infectious diseases.

Mairead Shaw is a Ph.D. student in Quantitative Psychology and Modelling at McGill University, advised by Dr. Jessica Flake. Her research interests include effect size measures in multilevel models, measurement equivalence in multi-group datasets, and the role of measurement in original and replication research.

Erica Moodie is Professor of Biostatistics and Canada Research Chair in Statistical Methods for Precision Medicine. Her research is primarily in causal inference for longitudinal data with a focus on adaptive treatment strategies. She has long-standing collaborations on the Canadian Co-infection Cohort, the largest cohort of people living with HIV and HCV, and is a statistical editor for the *Journal of Infectious Diseases* and an Associate Editor for *Biometrics*. She is also a member of the COVID vaccine development tracking website, https://covid19.trackvaccines.org/.

Derek Ruths is Associate Professor of Computer Science at McGill University and is serving on the COVID Alert Advisory Board. His ongoing academic work focuses on the responsible use of data science and machine learning for studying human behavior, especially using online data. His most recent contributions concern detecting and mitigating “bad behavior” online, including disinformation campaigns and abusive speech. In addition to his research and teaching, he runs Charitable Analytics International, a not-for-profit that advances and applies cutting edge data science to amplify social good initiatives in humanitarian organizations and governments.

Methods

Modeling

To assess the impact of Canada's COVID-19 exposure notification app, COVID Alert, on mitigating virus transmission, we estimate the number of COVID-19 cases averted in each province based on a modelling approach proposed by Wymant et al. The effect of notifications received on day *t* on the number of cases averted can be modelled as the product of five terms: (i) the number of notifications received on day *t*, (ii) the secondary attack rate (SAR), which is the probability that someone who is notified will test positive, (iii) the expected fraction of transmissions preventable if an infectious individual strictly adheres to quarantine after receiving a notification, (iv) the quarantine effectiveness, and (v) the expected size of the full transmission chain that would be originated by the contact if they had not been notified.

Due to the constraints of privacy-preservation, the SAR, the expected fraction of transmissions prevented, and the quarantine effectiveness cannot be estimated from the available data. We consider instead a range of plausible values for these parameters that are based on the literature (see Wymant et al. and Segal et al.). In particular, we consider SARs of 5% and 6%. Following the results in Ferretti et al., the *generation time* (i.e., the time from infection of the index case to the time of infection of the secondary case) is modelled by a distribution with an average generation time of 5.5 days. We, therefore, estimate the fraction of transmission prevented from the delay distribution using the above generation time distribution assuming that the *mean time from exposure to notification* among those app users is 5.46 days (as in Segal et al.); this correlates to approximately 50% of transmissions being prevented by receipt of exposure notifications. For the effectiveness of quarantine in reducing transmission, two plausible values of 45% and 65% were used (Wymant et al.; Segal et al.). The size of the transmission chain is a function of the number of cases during the study period. Here we followed the assumptions of Wymant et al.; specifically, it is assumed that local epidemics do not mix and that the extra cases do not affect the epidemic dynamic.

We estimated the number of deaths averted by multiplying the number of cases averted by the crude case fatality rate, which was estimated for each province as the ratio of its total number of deaths due to the COVID-19 virus during the modeling time period to its total number of cases during the modeling time period. Note that these rates are a lower bound because the time delay from illness onset to death leads to right censoring, that is, the true number of deaths among those cases will be equal or greater than the observed number at the end of the study since some people may die subsequent to the period of study.

Comparative assessment

To compare the adoption and usage of COVID Alert to that of similar apps deployed in other countries, we first sourced countries with apps from a Wikipedia list comprising 47 countries with official contact tracing apps (“COVID-19 apps,” 2021). We utilized the Google Scholar and larger Google search engines as well as news sources to obtain reports related to each app’s uptake and efficacy. We accepted only reports originating from sources with direct access to data, such as government reports or research reports from teams that worked directly with app data. Of the 47 countries with apps, we were able to identify 8 apps for which published reports were available: the United Kingdom (NHS COVID-19 app; Wymant et al., 2021), Switzerland (SwissCovid; Salathé et al., 2020), New Zealand (NZ COVID Tracker; Ministry of Health NZ, 2021), Germany (Corona-Warn-App; Hoerdt, 2021), Italy (Immuni; Presidenza del

Consiglio dei Ministri, 2021), France (TousAntiCovid; @TousAntiCovid; @cedric_o), Washington state (WA Notify; Segal et al., 2021), and the Netherlands (Corona Melder; Boncz, 2021).

We compared the adoption and usage of COVID Alert to similar apps deployed in other countries along five metrics: (1) app downloads, (2) active users, (3) exposure notifications sent, (4) estimated cases averted, and (5) estimated deaths averted. To facilitate fair comparisons, we considered these metrics with respect to the population and the total number of cases in the region served by the app. For countries, populations and total cases were drawn from Worldometer on July 27, 2021. For Washington state, the population and total case numbers were drawn from the United States Census Bureau and the New York Times, respectively (Allen et al., 2021; United States Census Bureau).

Results

Modeling

The daily numbers of cases and notifications sent were smoothed to 7-day moving averages to reduce the impact of short-term fluctuations and to highlight long term trends. The estimated number of cases averted and the estimated number of deaths averted between 03/03/2021 and 15/07/2021 are listed in Table 1 and Table 2 for each province considered. We limited the assessment to include only provinces that sent >200 notifications during the assessment period: Manitoba, Newfoundland and Labrador, Nova Scotia, Ontario, Quebec, and Saskatchewan.

Our analyses suggest that a large number of cases were averted by usage of the app. For the subset of provinces included in this assessment, the estimates range from approximately 6,284 to 10,894 cases averted, depending on the chosen parameters (Table 1). By multiplying each province-specific estimate of the number of cases averted by the province specific crude case fatality rate observed for the same period, we estimate the number of deaths averted to be approximately 57 to 101, depending on the parameters chosen.

The number of cases averted is positively related to the severity of the pandemic (and the total number of notifications sent), with higher numbers of averted cases in areas with high numbers of confirmed cases (see Table 3). Note that as the number of deaths is estimated as a simple fraction of the number of cases, the fraction of cases averted equals the fraction of deaths averted. The results show that the ratio of cases averted to confirmed cases is, in general, higher in areas where a larger proportion of the population adopted the app. For example, in the more optimistic quarantine scenario of 65% with the higher SAR of 6%, Newfoundland and Labrador, where the proportion of app users is 22.8%, had a higher ratio of cases averted to confirmed cases than Saskatchewan, where app usage was only 6.5%. This result suggests that a larger number of cases of COVID-19 were averted by contact tracing through the COVID Alert app in areas with a higher fraction of active app users in the population.

The analyses demonstrate that the adoption of the COVID Alert app contributed to mitigating the COVID-19 pandemic in Canada with estimated upper bounds equal to 10,894 cases averted and 101 deaths averted in the selected provinces between 03/03/2021 and 15/07/2021. Most notably, the results indicate that the proportion of app users is positively associated with the ratio of cases averted to confirmed cases, supporting the positive intervention effects of the COVID Alert app.

The main limitation of our analysis is the inability to estimate key parameters of the model due to the high level of data aggregation employed to preserve privacy. Rather than being estimated directly from Canada-specific data, these parameters had to be assumed, and were chosen based on the literature. Thus, the reliability of our findings is dependent on the fidelity of our assumptions to the truth, which are empirically untestable with the available data. In particular, the plausible values of the effectiveness of quarantine were estimated based on surveys in the UK and the USA, but it is difficult to assess their reliability and comparability to the effectiveness of quarantine in Canada. Furthermore, the fraction of the transmission chain prevented by notification depends on the time elapsed between exposure and notification, which could vary across the time period of the analysis. With the aggregate data available to us, we used a single estimated value for this study period, i.e., 5.46 days between exposure and notification. However, this assumption that there is no variation in elapsed time is not unreasonable in the period of assessment considered here as delay times for testing and reporting were more uniform by March 2021.

Table 1: Estimated number of cases averted between 03/03/2021 and 15/07/2021.

Province	**45% Quarantine Effectiveness**		**65% Quarantine Effectiveness**	
	5% SAR	**6% SAR**	**5% SAR**	**6% SAR**
Manitoba	662	795	956	1,148
Newfoundland and Labrador	172	206	248	298
Nova Scotia	232	279	336	403
Ontario	4,567	5,481	6,597	7,917
Quebec	349	419	504	605
Saskatchewan	302	362	436	523
Total	**6,284**	**7,542**	**9,077**	**10,894**

Table 2: Estimated number of deaths averted between 03/03/2021 and 15/07/2021.

Province	**45% Quarantine Effectiveness**		**65% Quarantine Effectiveness**	
	5% SAR	**6% SAR**	**5% SAR**	**6% SAR**
Manitoba	7	8	10	12
Newfoundland and Labrador	1	1	1	1
Nova Scotia	1	2	2	3
Ontario	42	51	61	74
Quebec	3	4	5	6
Saskatchewan	3	3	4	5
Total	**57**	**69**	**83**	**101**

Table 3: Number of cases, number of notifications sent, proportion of population that are active app users, estimated ratio of cases averted to confirmed cases, and estimated ratio of deaths averted to deaths due to the COVID-19 virus between 03/03/2021 and 15/07/2021.

Province	**Cases**	**Notifications**	**Proportion of app users**	**Ratio of cases averted to cases**		**Ratio of deaths averted to deaths**	
				Lower bound	**Upper bound**	**Lower bound**	**Upper bound**
Manitoba	25,078	5,622	9%	0.026	0.046	0.026	0.046
Newfoundland and Labrador	439	564	22.8%	0.392	0.679	0.392	0.679
Nova Scotia	4,227	1,288	12.9%	0.055	0.095	0.055	0.095
Ontario	244,900	55,388	9.7%	0.019	0.032	0.019	0.032
Quebec	87,168	4,138	7.9%	0.004	0.007	0.004	0.007
Saskatchewan	20,403	3,170	6.5%	0.015	0.026	0.015	0.026
Total	**382,215**	**70,170**	**9.4%**	**0.016**	**0.029**	**0.016**	**0.029**

Note: Lower bound: 5% SAR and 45% quarantine effectiveness; Upper bound: 6% SAR and 65% quarantine effectiveness.

In an ideal analysis of impact, we would provide impact estimates for the entire time period during which the app was used, i.e., since July 2020. However, exposure notification data was not tracked until late February 2021. To extend the analysis to this early period would require us to make assumptions about the number of exposure notifications sent each day. This statistic is highly dependent on the number of users, the clustering of users within the population, and the number of infections. Given the province-specific variations in infection rates as well as the resulting changes in population behaviour, any attempt to do this extrapolation would be highly speculative.

What we can say, however, is that trends in the number of downloads provides a strong indication that adoption of the app was higher in the months before February 2021. This almost certainly would correlate with more active users and more clustering of users within the population, which would result in more exposure notifications per case. We expect that the true ratios of cases averted and deaths averted over the entire period of app deployment are higher than we have been able to estimate with confidence here for this shorter period. However, we do not believe that these higher values would markedly change the trends and relative impact reported for the March - July 2021 time period.

Comparative assessment

Adoption and usage

Downloads and active users for each app considered are summarized in Tables 4 and 5. To facilitate comparison between apps, both downloads and active users are also presented as a percentage of the respective country or state population, and the number of active users is also presented as a percentage of downloads. The COVID Alert download rate was the lowest of the apps compared. Active users as a percentage of the population was among the lowest; however, active users as a percentage of downloads was comparable to other apps.

Table 4: App downloads by country.

Country	Downloads	
	Raw	Percent of population
Canada[a]	6,599,280	17.32%
France	25,000,000	38.21%
Germany	31,000,000	36.87%
Italy	12,168,758	20.15%
Netherlands	4,900,000	28.53%
New Zealand	2,903,866	59.69%
Switzerland	2,360,000	27.05%
United Kingdom	21,000,000	30.75%
USA - Washington state	2,000,000	26.26%

[a] Total downloads for the period of July 31, 2020 to July 15, 2021.

Table 5: Active app users by country.

Country	Active Users		
	Raw	Percent of population	Percent of downloads
Canada[a]	3,081,445	8.09%	46.69%
New Zealand[a]	611,710	12.57%	21.07%
Netherlands	1,740,000 - 2,714,400	10 - 15.6%	35.51 - 55.40%
Switzerland	1,620,000	18.57%	68.64%
United Kingdom	16,500,000	24.17%	78.57%

[a]Average number of active users for the month of March 2021.

Effectiveness

The total number of exposure notifications sent, the estimated number of cases averted, and the estimated number of deaths averted are summarized in Tables 6 - 8 as raw numbers and as a percentage of the total number of COVID-19 cases in each country or state. Note that the total number of cases used to obtain each percentage corresponds to the number of confirmed cases since the start of the pandemic; however, the apps were launched at various later dates. Thus, the efficacy numbers reported as a percentage of total cases are likely underestimates since there was no possibility of averting cases before the apps were deployed. Additionally, note that we have included our estimates of cases averted for Canada based on our six-province analysis in the table. Estimated efficacy information was scarce; only three of the eight countries had case and death aversion estimates available, and only four of the eight had exposure notification data available. Given the available data, our analyses suggest comparable efficacy between COVID Alert and the apps from Italy, France, and Washington state.

Table 6: Exposure notifications sent by country.

Country	Exposure Notifications Received	
	Raw	Percent of total cases
Canada	74,562	5.18 - 5.22%
France	200,037	3.32%
Italy	101,051	2.34%
United Kingdom	1,700,000	29.59%
USA - Washington state	34,501	7.32%

Table 7: Estimated cases averted by country.

Country	Estimated Cases Averted	
	Raw	Percent of total cases
Canada	6,284 - 10,894	0.44 - 0.76%
Netherlands	45,088	2.44%
United Kingdom	284,000 - 594,000	4.94 - 10.34%
USA - Washington state	8,547	1.81%

Table 8: Estimated deaths averted by country.

Country	Estimated Deaths Averted	
	Raw	Percent of total cases
Canada	57 - 101	0.004 - 0.01%
Netherlands	271	0.01%
United Kingdom	4,100 - 8,700	0.07 - 0.15%
USA - Washington state	40 - 115	0.01 - 0.02%

The main limitation of our comparative analysis is that the time periods over which each app reported usage and efficacy numbers are characterized by different waves of infection at different times. The dates spanned by different reports are summarized in Table 9. Not only do the reports span a variety of time periods, but it is difficult to know if a given report is an accurate representation of the overall usage and efficacy of an app or if it captures a period of particular efficacy or lack thereof.

Table 9: Time periods covered by COVID available app reports.

Country	Report timespan
Canada	March 2021 – July 2021
France	October 2020 – July 2021
Germany	June 2020 – July 2021
Italy	June 2020 – July 2021
Netherlands	October 2020 – May 2021
New Zealand	May 2020 – July 2021
Switzerland	July 2020 – September 2020
United Kingdom	October 2020 – December 2020
USA - Washington state	December 2020 – April 2021

Discussion

There are several key takeaways from our analysis.

When adopted widely, usage of the COVID Alert app averted a significant number of cases and deaths. Newfoundland and Labrador as well as Nova Scotia had relatively large active user bases, which translated into high estimated ratios of averted cases and averted deaths in these provinces. In contrast, provinces with smaller active user bases had much lower estimated ratios of averted cases and averted deaths. This correlation is not simply a product of our parameter assumptions; it is reflective of the underlying data, specifically the ratio of the number of exposure notifications to the population size. This result provides a strong indication that the COVID Alert app demonstrated its capacity to be an effective tool for mitigating infections and deaths due to COVID-19. However, this efficacy (much like vaccines and other public health instruments) is dependent on widespread adoption and use.

A key point to highlight is that adoption of the app does not simply mean downloading and installing the app; adoption also involves responding to exposure notifications (i.e., testing and adhering to quarantine guidelines) as well as entering one-time keys when a positive test result is received. While the data available do not allow us to directly assess the role of these different aspects of usage in the overall app impact, the highly non-linear relationship between the number of active users and the fraction of averted cases (see Table 3) suggests that these other aspects of usage contributed to the limited impact observed in provinces with single-digit adoption.

Nationally, the COVID Alert app had limited impact. Because the app was not widely adopted in the more populated provinces, the overall impact of the app was quite limited. For the provinces considered, the estimated numbers of cases averted and deaths averted are approximately equivalent to 1-3% of the number of confirmed cases and the number of deaths due to the COVID-19 virus, respectively.

Among the exposure notification apps considered in this assessment, the COVID Alert app had one of the lowest adoption rates. Attempting to compare the adoption rate of the app against other contact tracing apps is fraught with challenges due in part to the region-specific nature of the pandemic during the time periods reported. However, *among countries that reported adoption rates for their apps,* that of COVID Alert was comparatively low. Canada's adoption levels were so low that even if all factors attributable to the fluctuating nature of the pandemic could be accounted for, the assessment of a comparatively low adoption rate for COVID Alert would likely stand.

Insufficient reliable statistics exist to compare the relative impact of exposure notification apps. While we were hoping to compare the impact of the COVID Alert app against those from other countries, the results are too sparse to allow for a fair assessment. Certainly COVID Alert's impact was lower than the UK's app. However, beyond this, information from other countries is sufficiently incomplete as to make impact assessment comparison too speculative to be meaningful.

Recommendations

Conducting this analysis afforded our team the opportunity to closely reflect on the factors that dominated the overall impact of the app as well as how the data collected impacted the modeling we wanted to do versus the modeling we could in fact accomplish with the available data. Bearing this in mind, we offer the following recommendations for future exposure notification work.

Raise app impact through app adoption and proper use. As we saw, when the app was adopted widely, it had a notable positive impact. Unfortunately, in the most populous provinces, adoption was more limited and, as a result, the numbers of averted cases and averted deaths were low nationally. It is important to underscore that adoption does not just mean installing the app but also includes responding to exposure notifications as well as accessing and entering one-time keys in the event of a positive COVID-19 test result.

Design data collection with a specific modeling technique in mind. The data available, while useful, were incomplete for the modeling task, and likely for any impact-oriented modeling task. We certainly understand why protection of privacy was the prevailing concern when deploying the app, and it may have been hoped that greater privacy protection would lead to higher adoption. However, it is possible that had impact modeling been a design consideration at the outset, all of the data required for the assessment would have been collected from the day of deployment. It is important to recognize that the specific metrics needed to support a specific modeling objective (e.g., deaths vs. hospitalizations vs. mental health interventions) vary; this is why modeling design and data collection design need to be done in concert. That said, to give a sense for the data that would have enabled a more precise model of the COVID Alert app's impact, we needed at a minimum the following other metrics to properly parameterize the UK model: (1) the local region of the user (e.g., postal codes), (2) days from exposure to notification per user, and (3) number of days between a received exposure notification and the entry of a positive test result.

Given the urgency and time-constraints imposed by the pandemic, design coordination and consultation across countries may not have been feasible. However, going forward, it may be useful to coordinate with other countries such as the UK, where adoption rates were high and the data collected permitted estimation of the key model parameters.

Consider surveys as part of app roll outs. Modeling the efficacy of an app involves measuring non-app related behaviors - for example, the time from onset of symptoms to the beginning of quarantine. For this reason, collecting information through surveys or other means in parallel with the roll out of the app is vital. It is also critical to evaluate the characteristics of those who are (and are not) active app users. For example, the effectiveness of the app in averting cases could differ substantially if active app users are more likely to be healthcare workers, those with high-contact employment, or public transit users, than if they are more likely to be individuals who work from home.

Assess what is actually *needed* to protect privacy. There is an important balance that needs to be struck between protecting user privacy and collecting enough data to assess the usage and impact of a tool. While we would not advocate for compromising privacy, having now worked with the data collected, we wonder about the necessity of certain anonymizing or aggregating practices that severely hindered the modeling and analysis process. Said differently - perhaps some data collection practices might *seem* to enhance privacy but in fact, offer only limited privacy benefits and have an outsized negative impact on the ability to model impact or usage. As we were not privy to the data collection design process, we would only point out that there may be opportunities for being more precise when designing privacy-protecting mechanisms so as to allow more robust modeling and analysis of the efficacy of the app.

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