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Alireza Dianat

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# Assessing the impacts of COVID-19 on activity-travel scheduling: A survey in the greater Toronto area

Alireza Dianat<sup>a,\*</sup>, Jason Hawkins<sup>b</sup>, Khandker Nurul Habib<sup>c</sup>

<sup>a</sup> Department of Civil & Mineral Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario M4S 1A4, Canada

<sup>b</sup> Department of Civil & Environmental Engineering, University of Nebraska – Lincoln, 900 N 16th St, Lincoln, NE 68588, USA

<sup>c</sup> Percy Edward Hart Professor in Civil & Mineral Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario M4S 1A4, Canada

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## ABSTRACT

The COVID-19 lockdown provided many individuals an opportunity to explore changes in their daily routines, particularly when considered in combination with an ever-changing Information and Communication Technology (ICT) landscape. These new routines and alternative activities have the potential to be continued in the post-COVID era. Transportation planners must understand how routines vary to effectively estimate activity-travel scheduling. The purpose of this study is to determine the influence of the COVID-19 pandemic lockdown on activity-travel behavior and the adoption of ICT-based alternative options. A special emphasis is placed on predicting the long-term effects of this disturbance on activity-travel scheduling. This study examines the changes in the frequency and mode of completing five of the most repetitious tasks in the daily schedule (working, grocery and non-grocery shopping, preparing/eating meals, and visiting family/friends) during the lockdown and immediately after reopening. We find an increased preference for home meal preparation over online ordering and a reluctance to engage in in-person shopping until a substantial proportion of the population has acquired a vaccination against the virus. Respondents prefer to work from home if they have adequate access to home office materials (e.g., desk, chair, computer monitor). Individuals with children must also consider suitable childcare before considering a return to work.

## 1. Introduction

On the last day of 2019, the first confirmed case of novel Coronavirus (COVID-19) was detected in Wuhan, China ([Archived: WHO Timeline - COVID-19 \[Internet\], 2021](#)), and shortly thereafter, the virus spreads globally. Canada reported its first case on January 25th, 2020 ([From first cases to first vaccines: A timeline of COVID-19 in Canada - National | Globalnews.ca \[Internet\], 2021](#)) and by March 11th, 2020, the number of cases in Canada exceeded 100. To combat the virus's spread, the government of Ontario, Canada, declared a state of emergency on March 17th, 2020 ([From first cases to first vaccines: A timeline of COVID-19 in Canada - National | Globalnews.ca \[Internet\], 2021](#)). Subsequently, a series of restrictions were imposed on in-person activities and social gatherings ([Ontario, 2020](#)) forcing many travel destinations to close.

This is not the first time that an incident influenced peoples' activity-travel behavior. [Mokhtarian \(2009\)](#) highlights several studies

\* Corresponding author.

E-mail addresses: [alireza.dianat@mail.utoronto.ca](mailto:alireza.dianat@mail.utoronto.ca) (A. Dianat), [jason.hawins@unl.edu](mailto:jason.hawins@unl.edu) (J. Hawkins), [khandker.nurulhabib@utoronto.ca](mailto:khandker.nurulhabib@utoronto.ca) (K.N. Habib).

on former transportation disruptions that look at how a disruption results in the alteration of individuals' conduct. According to these studies, transportation disruption motivated people to consider Information and Communication Technology (ICT) solutions for their daily activities, such as replacing work travel with telecommuting. During the COVID-19 pandemic, similar to previous disruptions, many individuals utilized ICT-based alternatives to perform their daily activities. However, the use of ICT became more popular and/or frequent during the COVID-19 lockdown since the in-person solutions for many activities were not available at all.

The first step in determining how the COVID-19 disruption influenced everyday behavior and encouraged ICT-based alternatives is to compare potential changes in daily activity. To this end, the frequency of using various options to perform activities should be measured for different time periods before, during, and perceived after the COVID-19 lockdown condition. Any significant changes in the utilization of ICT-based alternatives might indicate the emergence of new daily activity habits. However, the more important question is how stable these ICT-based solutions would be when COVID-19 is no longer a threat. If new ICT-based behaviors are shown to be stable, they should be included in daily scheduling models.

Variations in behavior should be taken into account when developing scheduling models for estimating individual activity plans throughout the day. The activity-travel scheduling model forecasts the choice of activity type, time, and duration in addition to the activity location and mode of travel (Miller and Roorda, 2003). The list of daily activities in different scheduling models includes but is not limited to: work; study; shop; prepare/eat meals; visit family/friend; sport; leisure; health and personal care; give/receive a ride; home chores (Nurul Habib, 2018; Hafezi et al., 2019). Most prior research on travel-related impacts of disruptions focused primarily on a few types of daily activities (e.g. working and/or shopping activities (Parkes et al., 2016; Brewer and Hensher, 2001; Larson and Shin, 2018) and neglected other frequent ones (e.g. socializing and meal preparation/eating). This article contributes to the literature by addressing the impact of COVID-19 disruption on a broader range of daily activities.

Accordingly, this research contributes to the literature by checking hypotheses of adopting new routines during the COVID-19 pandemic and their probable continuity after a complete return to normal. From the list of activities, we focused on the most frequent daily activities in this research: working/studying, grocery and non-grocery shopping, preparing/eating meals, and visiting family/friends. This study intends to see if the responder considered alternate methods of accomplishing these activities during the pandemic, to see if these new methods can replace earlier ones in the future.

The remainder of the paper is structured as follows: in the next section, a review is provided of the related literature. Then, an explanation given of the data and data collection methods. Preliminary findings are presented. To test our hypotheses and elicit findings, two statistical models are estimated in the next section. Finally, conclusions and future works are outlined.

## 2. Literature review

ICT facilitates the pervasiveness of technology-based services in modern life. In the transportation sector, ICT is at the heart of a slew of new enterprises that are reshaping travel options and behavior. For commuters who do not own a car, for instance, online carsharing services provide access to a private vehicle as a new mobility option (Ben-Elia et al., 2018). Between ICT and activity-travel behavior, the research identifies four distinct types of relationships: substitution (replace/reduce travel), complementarity (increase travel), modification (change travel pattern), and neutrality (do not affect travel) (Salomon and Mokhtarian, 2007). This study aims to determine the relationship between ICT and various daily activity-travel behaviors.

Several previous studies attempted to determine the impact of ICT on various in-person activities and/or travel behaviors. The majority of the prior research has only focused on the impact of ICT on mandatory or maintenance activities (e.g., working (Andreev et al., 2010; Elldér, 2020) and shopping (Weltevreden, 2007; Farag et al., 2006) in non-emergency conditions, though some examples exist for ICT impacts on other types of activities (e.g., socializing (De Abreu et al., 2017; Matous, 2017), leisure (Cao et al., 2007). To the best of the authors' knowledge, before the COVID-19 pandemic, the literature on the impact of ICT on travel behavior during and after a disaster is limited to the working and shopping activities. The two following sections summarize some previous studies in the literature on ICT implementation in working and shopping activities during and/or after transportation emergencies.

### 2.1. Working activity-travel behavior

Substitution and modification (travel time/mode/route) are the most likely ICT solutions for working travel (Elldér, 2020), especially when the workplace or transportation system lost its functionality and/or safety (Mokhtarian, 2009). According to Mokhtarian (Mokhtarian, 2009), potential threats to the functionality and safety of the workplace or transportation system can be divided into three categories: planned extreme events (e.g., Olympics, World Cup), natural disasters (e.g., fires, floods, earthquakes, blizzards, hurricanes), and terroristic attacks (Gigerenzer, 2006).

An example of a planned travel disruptive event is the Olympic games (Mokhtarian, 2009). The transportation system of the host city (or cities) receives a significant increase in demand during these events, which may exceed the capacity at particular locations, referred to as "hot-spots" (Parkes et al., 2016). Some transport demand management (TDM) scenarios are proposed to organize this transport emergency such as travel behavior change (Currie and Shalaby, 2012) and reducing/re-timing the journey (Parkes et al., 2016). According to Brewer and Hensher (Brewer and Hensher, 2001), Sydney citizens' work activity-travel behavior during the 2000 Olympic Games was expected to change based on their behavioral intentions before the event. Their hypothesis was tested by examining observed behavior during the games (Brewer and Hensher, 2001). Parkes et al. (Parkes et al., 2016) investigated how travel behavior would change due to the 2012 Olympics in London. Reducing, re-timing, re-routing, and re-moding travel were four adaptation scenarios suggested by the event organizers to avoid demand overflow at hot-spots during the peak period. The most likely adaptation options made during the event are reducing total travel (including telecommuting and working elsewhere (Transport for

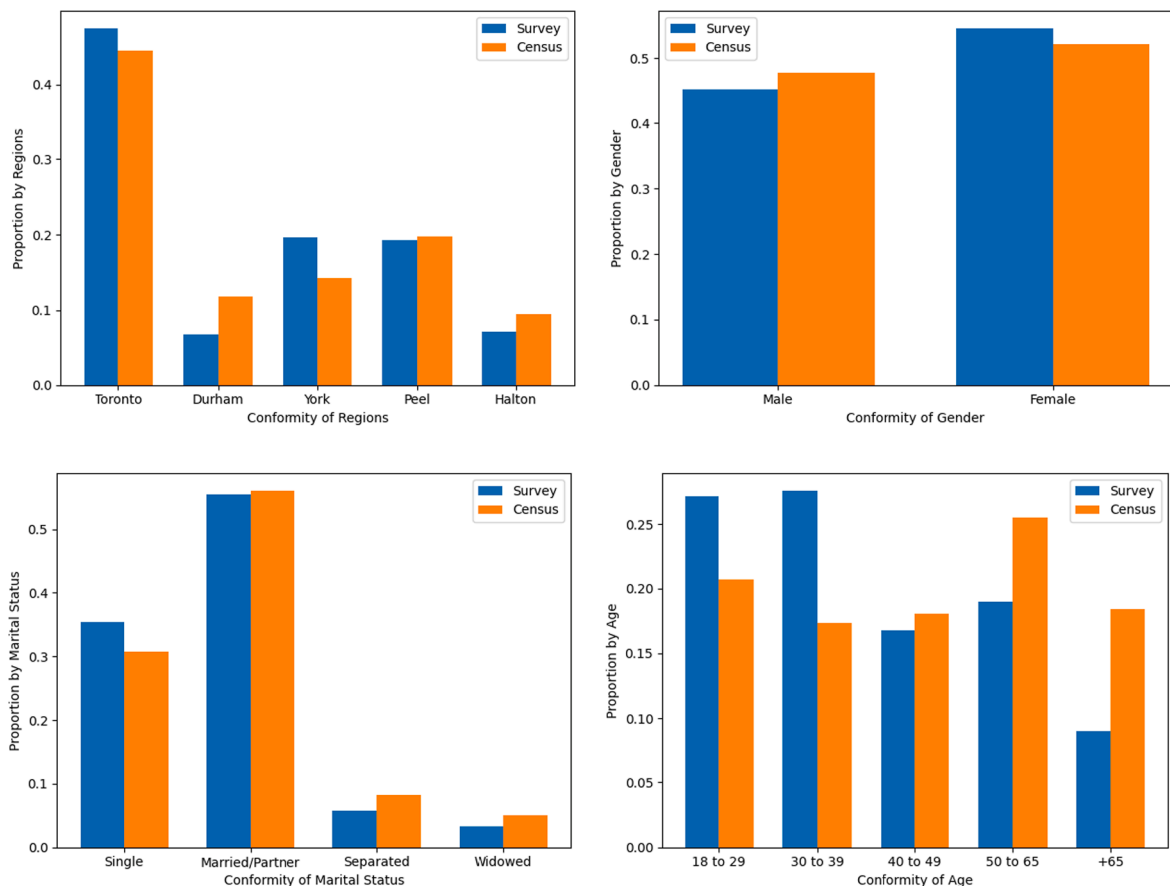


Fig. 1. Several checks for conformity of sample and population.

London. Olympic Legacy Monitoring: Personal Travel Behaviour during the Games Travel in London Supplementary Report, 2013) and re-timing trips. The study found that while the Olympic event can influence visitors' behavior in the short term, the changes do not persist after the event is over (Parkes et al., 2016).

Also, natural catastrophes such as floods (Lu et al., 2017), earthquakes (Pratt, 1991; Wesemann et al., 1996), blizzards (Wang et al., 2017), or hurricanes (Larson and Shin, 2018; Wang and Taylor, 2014) can alter activity-travel behavior. Individuals can even change their travel habits in response to changing weather conditions (Cools et al., 2010). The more important question is whether these alterations will persist even after conditions have returned to normal. According to Pratt (Pratt, 1991), after the 1989 earthquake in San Francisco, telecommuting was discovered to be a flexible answer to the associated transportation emergencies. Moreover, they discovered that around half of the new telecommuters kept working from home for another 2–6 months. This result can be read as the long-term shift in travel behavior as a result of a short-term behavior change in response to an emergency (Pratt, 1991). Wesemann et al. (Wesemann et al., 1996) looked into how car-driver travelers' reacted to the Northridge earthquake's damage to various main roadways in Southern California. They suggest, after the motorway was reopened, about 74% of commuters who moved from automobile to rail due to the disruptions would continue to use it for a short time thereafter. Even 3 months after the motorway reopened, 55% of the new train users continued to use the train for a variety of reasons, such as reliability (Wesemann et al., 1996).

## 2.2. Shopping activity-travel behavior

Some previous studies shed light on how emergency conditions influence shopping behavior. Larson and Shin (Larson and Shin, 2018) list several former man-made disasters that affected shopping behavior, including war, terrorist attacks, and pollution. Several studies look at consumer expenditure patterns during an epidemic outbreak (Jung et al., 2016) as well as how it changes over time (Kennett-Hensel et al., 2012). Some other studies look into how, and to what extent, fear of an emergency situation can affect purchase behavior (Hutjens, 2014; Kaur et al., 2020). However, to the best of the authors' knowledge, no research on the choice of purchasing mode (in-store or online) during or after an emergency has been done before the COVID-19 pandemic.

This study adds to the body of knowledge by looking at the effects of a pandemic on a variety of activity-travel behaviors over time with a focus on the potential new patterns in the utilization of ICT solutions. Given the continuous nature of the pandemic, this research serves as a baseline for the pandemic's impact on activity behavior changes in the middle of the lockdown period. Through revealed

**Table 1**  
Example SP Scenario for Workplace Choice.

Attributes	COVID risk level		
	Everyone has been vaccinated		
	Work from home	Hybrid workplace (2–3 days teleworking)	Work in the workplace
Technologies at home	Internet + Laptop	Internet + Laptop	–
Furniture at home	Work desk + Chair	Work desk + Chair	–
Shifting work hour	Allowed	Allowed	Allowed
Splitting work hour	Not allowed	Not allowed	–
One-way travel time from home to workplace	–	More than 60 min	More than 60 min
Level of crowding at workplace	–	Normal crowding, 6 feet distance is achievable	Normal crowding, 6 feet distance is achievable
Child caring	In-home without nanny	In-home without nanny	Child care

**Table 2**  
Example SP Scenario for Shopping Method Choice.

Attributes	COVID risk level		
	No vaccine has been found yet		
	E-shopping	In-store, Supermarket	In-store, Wholesale market
Delivery time	One to two days	–	–
Delivery fee	10\$ delivery fee	–	–
Saving purchase basket	Yes	–	–
One way travel time	–	More than 30 min	More than 45 min
Level of crowding	–	No crowding, there are more than 6 feet distance	High crowding, 6 feet distance is not achievable
Waiting time in line to enter the store	–	More than 30 min	15 to 30 min

activity pattern data, this study investigates the immediate effect during the lockdown as well as the short-term implications following re-opening. Additionally, the long-term stability of acquired behaviors was predicted using both a series of stated preference trials and respondents' self-reported behavior in a post-pandemic context.

### 3. Survey

The information utilized in this study was gathered using an online survey between July 12th and July 24th, 2020, when Ontario began the second phase of reopening (except in a few locations) following the first prevalent shutdown ([From first cases to first vaccines: A timeline of COVID-19 in Canada - National | Globalnews.ca \[Internet\], 2021](#)). The social gathering limit was extended from 5 to 10 people during this phase of the reopening, and outdoor activity centers and enterprises such as shopping centers and restaurants were allowed to reopen with sufficient health and safety measures. The study area encompasses the Greater Toronto Area's (GTA) five subdivisions: Toronto, Halton, Durham, Peel, and York. The data collecting process was contracted out to Canadian Viewpoint<sup>1</sup>. A random sample of 1000 respondents was drawn using stratified random sampling according to each subdivision's population proportion ([Statistics Canada, 2020](#)). After cleaning the data, 985 distinct records were filtered for analysis.

To ensure that the sample is representative of the population, the proportions of regions are limited to reflect the census distribution. Additionally, the sample's conformance was determined by comparing it to several reference factors ([Fig. 1](#)). The acquired data closely reflects the population's demographics of gender and marital status. The age distribution is tilted toward the younger end of the population which means the sample overrepresents young people while underrepresenting older people. Given the negative association between age and the employment of ICT-based alternatives, disregarding this mismatching issue may result in subsequent analysis's validity issues. To address this issue, an Iterative Proportional Fitting (IPF) technique was used to ascertain the weight of each age group in each region. Overall, the conformity distributions attest to the survey panel's representativeness, given that we only set explicit quotas on the geographical distribution.

The questionnaire collected data on individual and household characteristics, activity-travel behavior before, during, and after the lockdown (based on their self anticipation), personal attitudes about workplace and shopping methods, and COVID-19-related questions. Additionally, respondents were given two sets of stated preference experiments, one concerning workplace selection and the other with grocery shopping method selection. Eight scenarios for workplace selection and an equal number for shopping mode selection were depicted for respondents. Scenarios were developed using the orthogonal fractional factorial design approach using the Ngene program ([ChoiceMetrics, 2021](#)).

[Tables 1 and 2](#) include examples of choice experiments displayed to respondents. Along with the alternative particular features, the scenarios incorporated vaccination rate attributes to further understand how a lethal illness might affect activity-travel choices. The "child-caring" attribute was omitted from the workplace choice scenarios for respondents who said they do not have children in their

<sup>1</sup> <https://canview.com/about-us/>.

**Table 3**  
Attributes and Attributes Levels of Workplace Choice.

	Attributes	Levels
Work form home	Facilities	Laptop
		Internet + Laptop
	Workplace	Internet + Laptop + Secondary monitor/Printer
		Dining table
		Work desk + Chair
Work in workplace	Shifting work hour	Fully furnished office room
	Splitting work hour	Shifting the start time is possible
		Shifting the start time is not possible
	One way travel time	Splitting the working hours is possible
		Splitting the working hours is not possible
General variable	Shifting work hour	Less than 10 min
		10 to 30 min
		30 to 60 min
		More than 60 min
	Level of crowding	Shifting the start time is possible
		Shifting the start time is not possible
	Child caring	No crowding, there are more than 6 feet distance
		Normal crowding, 6 feet distance is achievable
		High crowding, 6 feet distance is not achievable
		In-home without nanny
COVID risk	In-home with nanny	
	Child care	
	No child	
	No vaccine has been found yet	
		40% of people have been vaccinated
		80% of people have been vaccinated
		Everyone has been vaccinated

**Table 4**  
Attributes and Attributes Levels of Shopping Method Choice.

	Attributes	Levels
E-shopping	Delivery time	Less than 5 h
		5 h to one day
		One to two days
		More than two days
	Delivery fee	Free
Physical shopping	Saving purchase basket	Free for more than \$50 purchase
		\$5 delivery fee
		\$10 delivery fee
	One way travel time	Yes
		No
	Level of crowding	Supermarket
		<10 min.
		10–20 min.
		20–30 min.
		>30 min.
General	Waiting time in-line to enter the store	No crowding, there are more than 6 feet distance
		Normal crowding, 6 feet distance is achievable
		High crowding, 6 feet distance is not achievable
		< 5 min.
	COVID risk	5–15 min.
		15–30 min.
		>30 min.
	COVID risk	No vaccine has been found yet
		40% of people have been vaccinated
		80% of people have been vaccinated
		Everyone has been vaccinated

household. “Saving purchase basket” indicates whether or not the list of things purchased the previous time will be saved for future online purchases. Tables 3 and 4 summarize the attribute levels for workplace choice and shopping method choice, respectively.

#### 4. Survey data analysis

This section presents a set of analyses of the frequency and duration of several activity-travel behaviors during the lockdown to

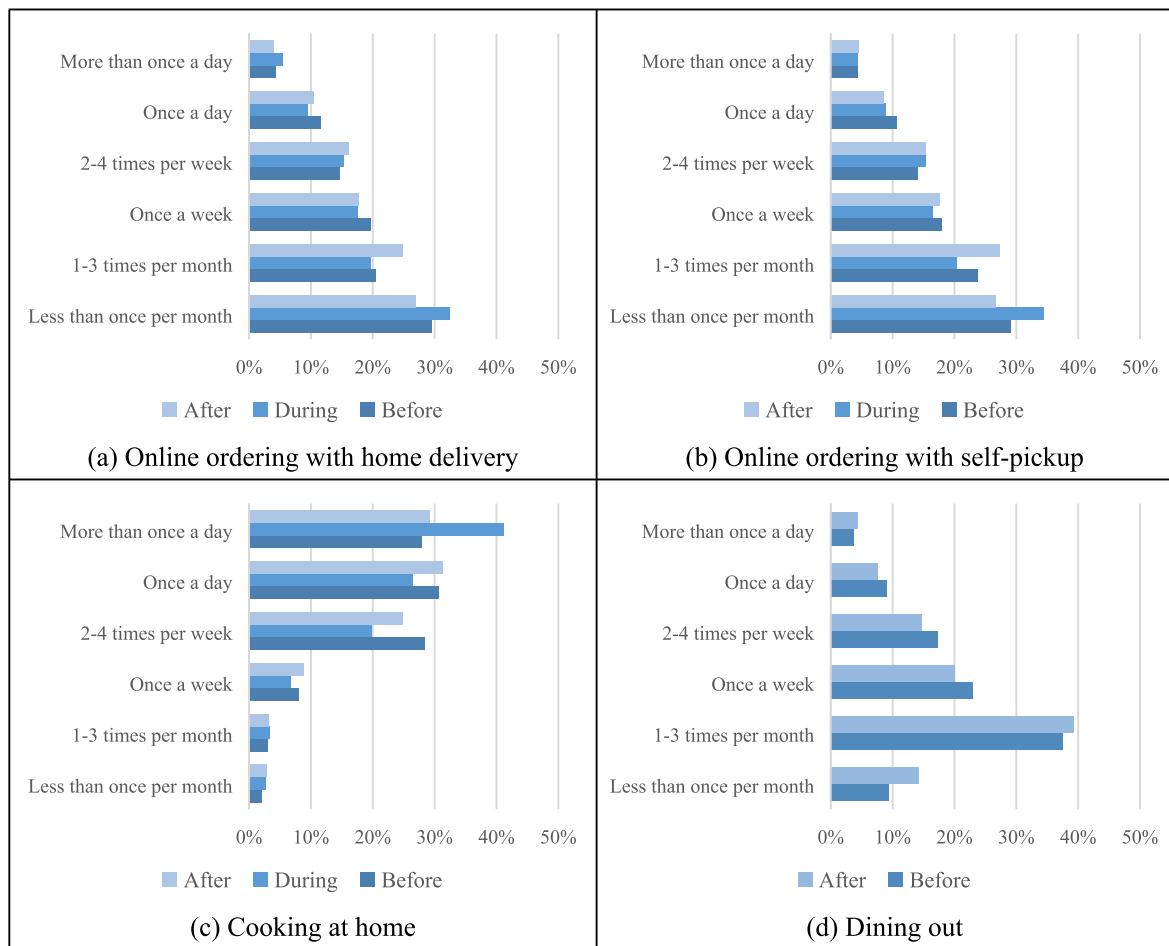


Fig. 2. Frequency change of various preparation/eating meal options.

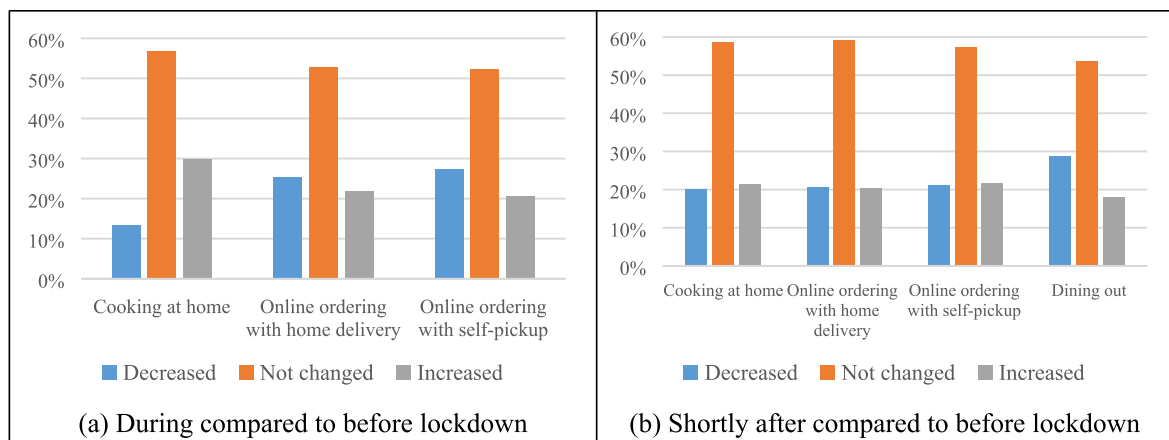


Fig. 3. Frequency change in use of various preparation/eating meal options compared to before the pandemic condition.

discover possible changes in daily routines. To this end, five behavior categories (preparing/eating meals, visiting family/friends, grocery and non-grocery shopping, and working) are examined at three time points: before, during, and immediately after the lockdown.

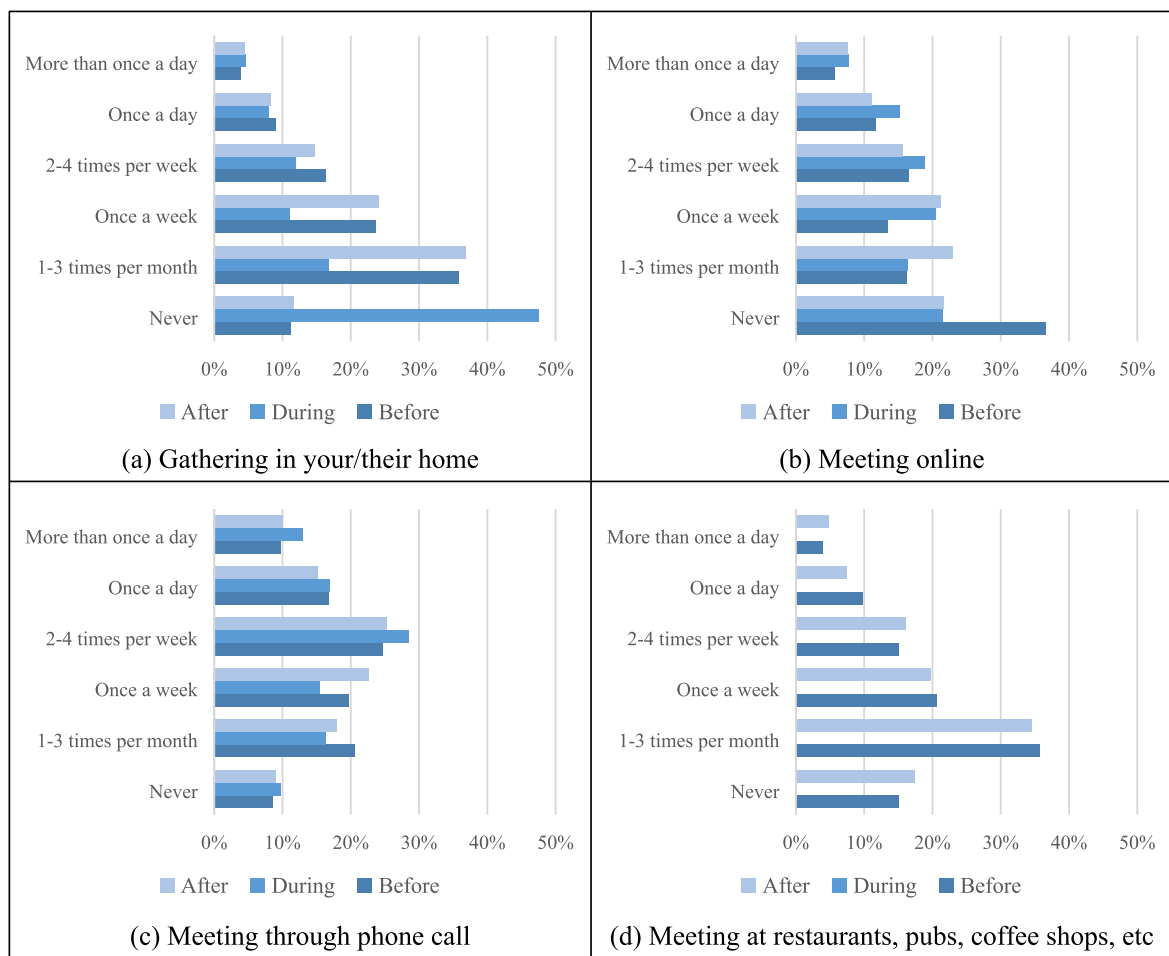


Fig. 4. Frequency change of various visiting options.

#### 4.1. Preparing/eating meals

Although restaurants were unable to provide in-store services during and immediately following the lockdown, many of them continued to operate using ICT solutions (online ordering and home delivery services). There are few research in the literature that examines the influence of ICT on food consumption behavior. [Dias et al. \(2020\)](#) recently studied how ICT can affect meal consumption, especially dining out. However, dining out or purchasing food online are not the only options for the broad “meal consumption” activity. Taking a step back, food for consumption is classified into two groups based on the method of preparation: 1) self-cooked; and 2) purchased. Thus, four different meal preparation and consumption methods are envisaged in this study: online ordering with home delivery, online ordering with self-pickup, cooking at home and dining out.

[Figs. 2 and 3](#) depict two viewpoints on changes in food consumption across three time periods. The frequency with which various food consumption alternatives were used before, during, and after the COVID-related limitations were implemented is depicted in [Fig. 2](#). [Fig. 3](#) compares the frequency of use of each option during and after the lockdown to the relative frequencies before the lockdown. According to [Fig. 2](#), the frequency of online food purchases fell during the lockdown compared to normal conditions, particularly for orders requiring in-person pickup ([Fig. 2 \(a\) & \(b\)](#)). This is likely owing to the danger of infection. As the percentage of at-home cooking grew dramatically during the lockdown ([Fig. 2 \(c\)](#)), the share of online ordering appeared to shift to at-home cooking. Thus, for many individuals, ICT was replaced by at-home meal preparation during the disturbance. In other words, there was a reverse substitution away from the ICT-based methods of food consumption. However, this modification does not appear to endure even for a few while following reopening ([Figs. 2 and 3](#)). As seen in [Fig. 3 \(a\)](#), those who did not indicate a change in their eating/preparation patterns constituted more than 50% of respondents during the lockdown (short-term). Additionally, this proportion would increase immediately following the lockdown to represent the likelihood that new-routine adopters would revert to their pre-pandemic level of meal preparation/eating alternatives. Additionally, data indicate a modest decrease in “going to a restaurant” behavior. This observation might be explained by the fact that susceptible individuals were avoiding this choice owing to their anxiety about COVID-19. In conclusion, our findings reveal that for the majority of respondents, eating/preparation activity remained unchanged shortly after



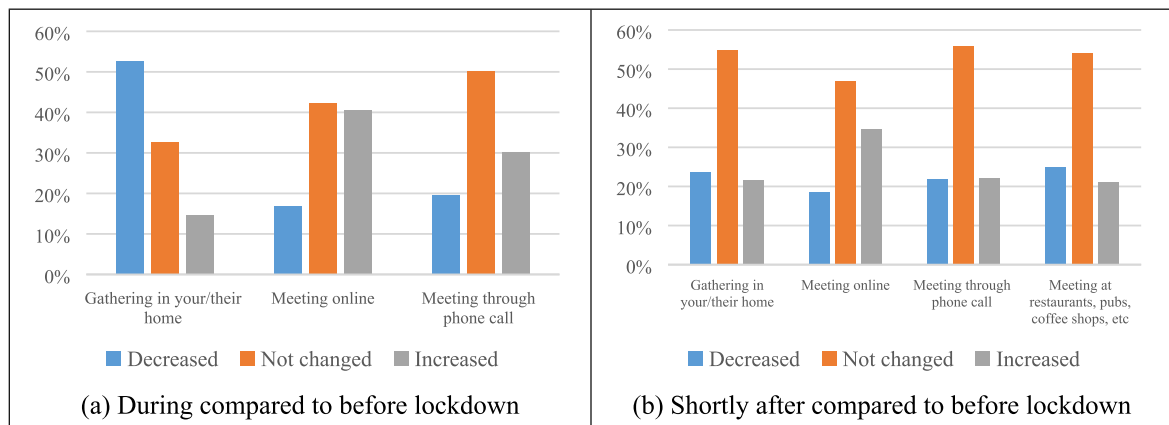


Fig. 5. Frequency change in use of various visiting options compared to before the pandemic condition.

lockdown.

#### 4.2. Visiting family/ friends

The influence of information and communication technologies on social life is a largely unsolved issue in the literature. Earlier research has discovered contradictory connections between physical and online social activity. A substitution pattern is found in some cases (Tilahun et al., 2015; van den Berg et al., 2013), while others find a complementary effect (Kamargianni, 2014; Kamargianni and Polydoropoulou, 2014; Nobis and Lenz, 2009; van den Berg et al., 2012), or neutrality (Kenyon, 2010). In this study, the physical and virtual options for visiting family/friends are investigated in the following distinct categories: gathering in your/their home; meeting online; meeting through a phone call; and meeting at restaurants, pubs, and coffee shops. The frequency of visits before, during, and after lockdown are compared in Fig. 4. The frequency of usage of each approach during and after the lockdown is compared to its relative frequency before the lockdown in Fig. 5.

Fig. 4 demonstrates that most respondents are meeting in-person less often during the pandemic, except for those who gather more than once a week. This change, however, does not seem to persist in post-pandemic conditions, as respondents claimed they would revert to their pre-pandemic level of gathering. In contrast, contact through the phone was discovered to be more frequent just during the lockdown. Meetings outdoors also seem to be mostly unaffected by the pandemic. However, many respondents reported experiencing the ICT-based alternative (online meeting) during the pandemic. Among individuals who had never used online meetings prior to the outbreak, 40% began utilizing them at least a few times each month. The data indicates that online meetings were used more often during the lockdown and will continue to be used more frequently in the future than in the pre-pandemic period.

Due to the restriction on physical gatherings during the COVID-19 lockdown, a significant decline was observed in at-home gatherings during this time (Fig. 5). Among about 67% of respondents who changed their at-home gathering behavior, more than 52% of them decreased their physical gathering (Fig. 5). Respondents mostly used ICT solutions as a substitute for the physical gathering during the lockdown (Fig. 5, 40 percent increase in online-meeting and 30 percent increase in phone calling during the lockdown compared to before). Respondents stated that they would return to the previous level of using phone communication within a short time after the shutdown. At-home and out-of-home gatherings would also return to about the same level, if not entirely, owing to safety concerns. A noteworthy finding is that respondents considered online meetings to be attractive and want to continue participating in them in the future. This recommends that a new routine (online meeting) should be adopted in the near future.

#### 4.3. Shopping

Earlier research has provided different conclusions about the influence of ICT on shopping. While some investigations (Weltevreden, 2007; Ferrell, 2005; Shi et al., 2019) revealed a substitution pattern (Weltevreden, 2007; Ferrell, 2005; Shi et al., 2019); others showed a complementarity impact (Frag et al., 2006; Frag et al., 2007; Frag et al., 2005). Also, some modifications (Frag et al., 2006; Ferrell, 2005; Frag et al., 2007) and neutrality effects (Calderwood and Freathy, 2014; Sim and Koi, 2002; Mokhtarian, 2008) are discussed. Recent research, on the other hand, that concentrated on a single product had more consistent findings. For example, e-shopping is frequently used as a substitute for in-store purchasing when it comes to groceries (Dias et al., 2020; Suel et al., 2015; Suel et al., 2018). However, according to some studies (Dias et al., 2020; Circella and Mokhtarian, 2010); ICT is a complement to in-store buying for non-grocery goods. As a result, it appears grocery and non-grocery buying behavior should be studied separately.

##### 4.3.1. Grocery shopping

Grocery stores were one of the few shopping destinations that stayed open in Canada during the pandemic. To ensure the safety of senior citizens and fragile persons, several establishments have allocated an hour to them exclusively. Additionally, several stores

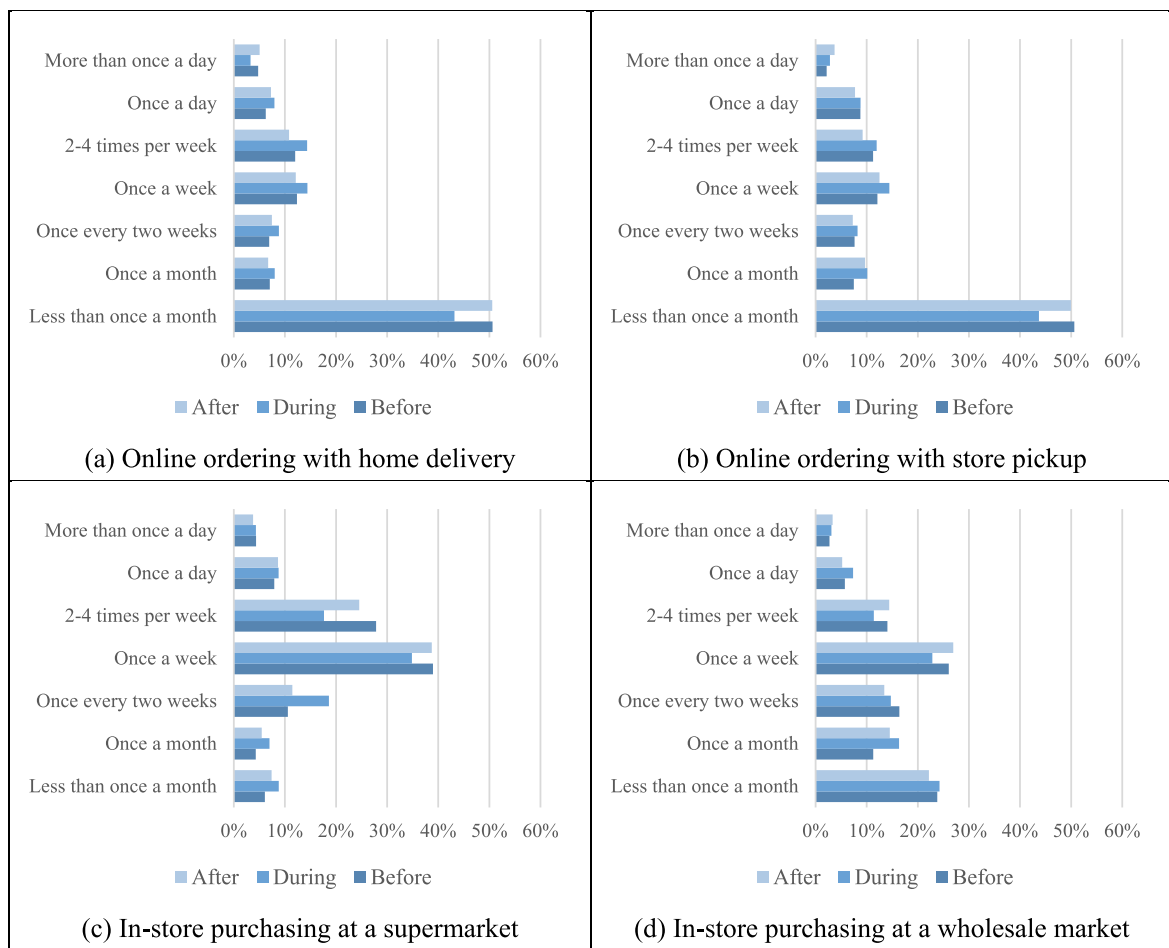


Fig. 6. Frequency change of various grocery shopping options.

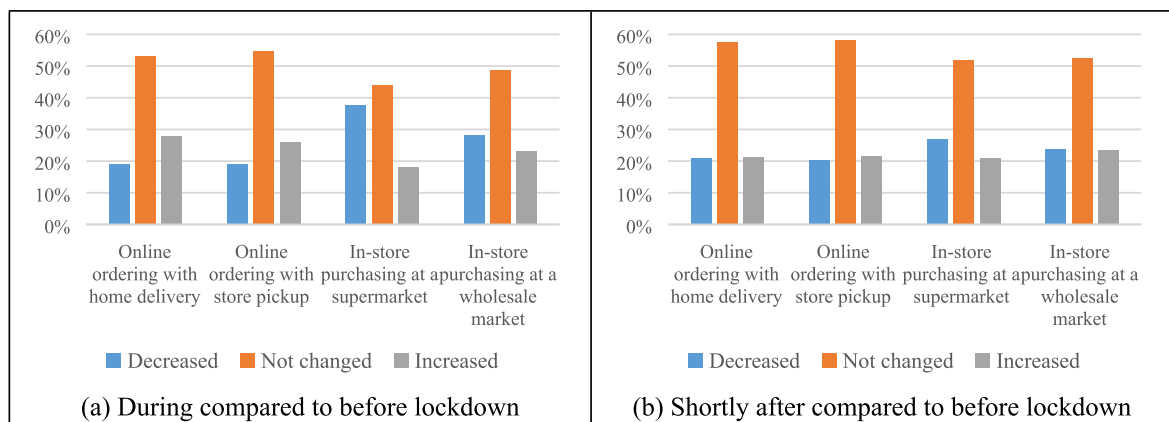


Fig. 7. Frequency change in use of various grocery shopping options compared to before pandemic.

offered online ordering with in-place delivery. In terms of behavior change, ICT may contribute to in-store purchasing in a variety of ways: e-shopping can act as a replacement for individuals who choose or are required to remain at home, or as a supplement to items that are sold out in shops (e.g., hand sanitizer or face mask). Additionally, it may provide a modified buying habit for those who establish new routines. In this research, four grocery shopping methods are considered: online ordering with home delivery, online ordering with store pickup, in-store purchasing at a supermarket, and in-store purchasing at a wholesale market. Notably, respondents

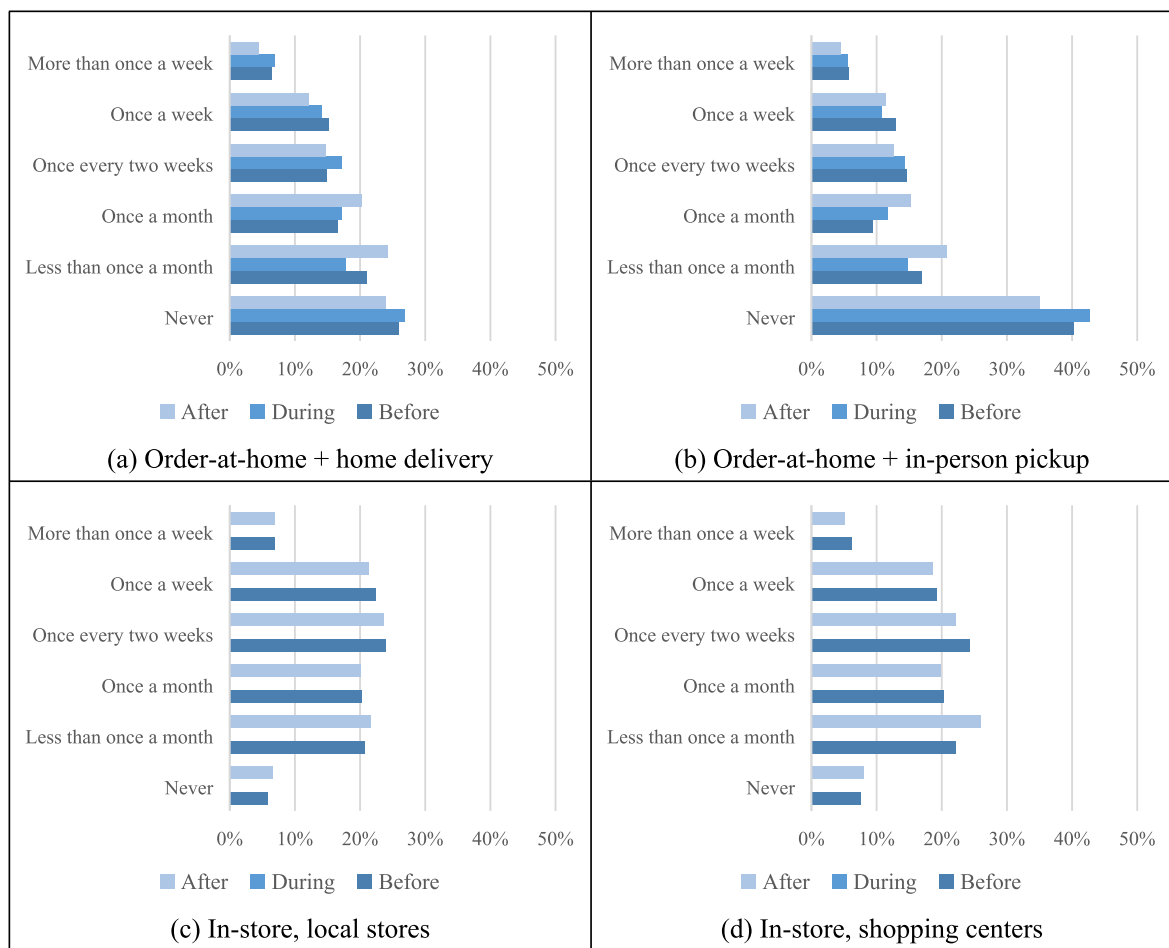


Fig. 8. Frequency change of various non-grocery shopping options.

had the option of selecting several modes of purchasing and were obliged to provide a different frequency for each. The frequency of visits was examined before, during, and after lockdown circumstances (Fig. 6). Fig. 7 depicts these findings as deviations from respondents' pre-lockdown behavior.

According to Fig. 6 (a) and (b), during the lockdown, 14% of "less than once a month" online buyers increased their e-shopping frequency. According to Fig. 7 (a), 28% of respondents reported a rise in their usage of online shopping with home delivery during the lockdown, the biggest increase of any manner of purchasing. Significant declines in in-store shopping were reported during the pandemic, particularly among people who used to shop once/a few times a week, but increases were reported in lower frequency buying, such as "once every two weeks" and "once a month" (Fig. 6 (c) and (d)). As opposed to 18% who indicated they shopped more often at supermarkets during the lockout, 37% of our sample stated they shopped less frequently at these establishments.

When respondents' shopping behaviors were compared before and during the lockdown (Fig. 6 and Fig. 7 (b)), no significant change in grocery shopping behavior was seen in the sample. The data suggest that individuals would revert to their pre-lockdown behavior after the pandemic. Given the availability of an in-person alternative during the lockdown, this unwillingness to modify grocery purchasing habits is understandable. While it is possible to wait in line for a half-hour to enter a store (in order to preserve social distance inside the store), respondents did not consider this was a strong reason to choose the ICT-based solution.

#### 4.3.2. Non-grocery shopping

During the COVID-19 lockdown, practically all non-grocery shopping in Canada was conducted via e-shopping since all the shopping destinations were closed. Additionally, the exceptional discounts offered by numerous retailers enticed people to purchase online (Thomas, 2020). These two factors combined to create a powerful incentive for non-grocery e-shopping to grow. However, there appear to be some significant barriers to e-shopping during the lockdown, such as revenue loss due to job loss (Statistics Canada, 2020) and lengthy delivery times (Schoolov, 2020). This section explores the effects of the pandemic lockdown on non-food shopping. The survey indicates four possibilities for non-grocery shopping: online ordering with home delivery, online ordering with store pickup, in-person purchasing from local businesses, and in-person purchasing from shopping centers. In three time periods, respondents were asked how frequently they utilized each alternative for non-grocery shopping. Fig. 8 compared the frequency of using each alternative

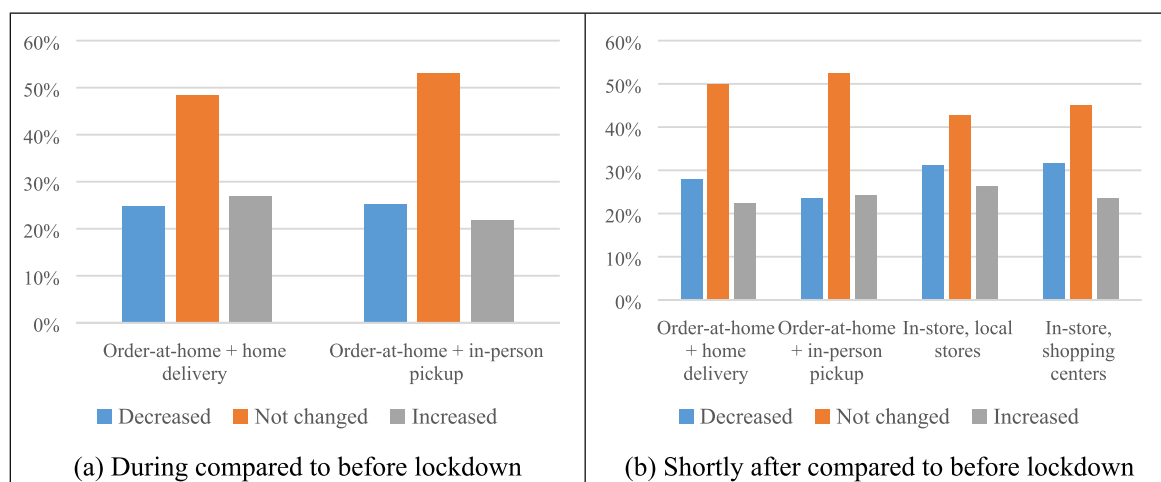


Fig. 9. Frequency change in use of various non-grocery shopping options compared to before pandemic.

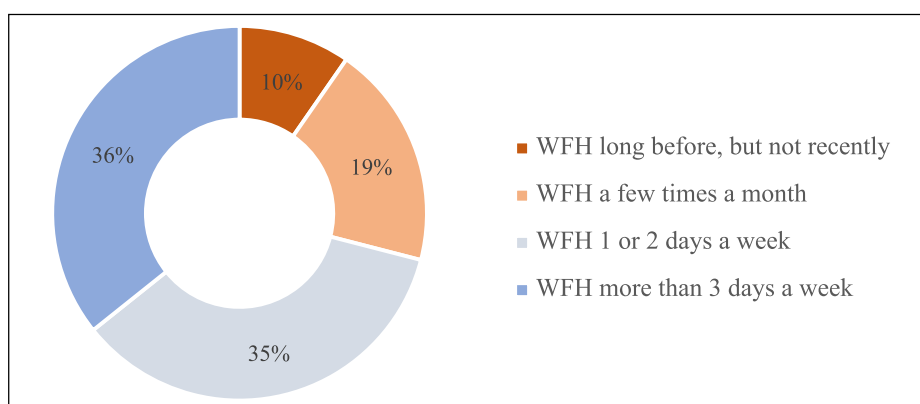


Fig. 10. Frequency distribution of work from home (all categories together) before the lockdown among experienced teleworkers.

before, during, and after lockdown circumstances. Fig. 9 illustrates these findings as deviations from respondents' pre-lockdown behavior.

According to Fig. 8 (a) and (b), it is expected to have new customers for non-grocery online shopping. The proportion of persons who had never purchased non-grocery items online prior to the pandemic reduced by 7.5% and 12.5% in post-pandemic conditions for shopping with home delivery and self-pickup, respectively. Thus, COVID-19 disruption underlies a change in non-grocery shopping behavior by encouraging online purchasing. As seen in Fig. 8 (c) and (d), in-store purchasing from both local retailers and shopping centers is predicted to decline in the post-pandemic situation compared to the pre-pandemic period.

Comparing drops and rises in non-grocery online purchasing before and after the pandemic lockdown lifted (Fig. 9), it is expected that 8% of respondents would reduce their in-store shopping at shopping centers in post-pandemic conditions. For shopping at local shops, a similar pattern was found, albeit with less intensity. According to Fig. 9 (a), respondents who reported a shift in their frequency of non-grocery shopping activity during the pandemic lockdown are more interested in having their purchases delivered than in picking them up. Additionally, it is projected that following the lockdown, both in-store and online non-grocery buying would decline in comparison to pre-pandemic levels (Fig. 9 (b)).

#### 4.4. Working

The impact of telecommuting, a well-known ICT-based activity, on activity-travel behavior has been comprehensively explored in the literature from several perspectives (e.g. travel frequency, travel distance, and time scheduling of travel (Graaff, 2004; Vora and Mahmassani, 2002; Mokhtarian, 1991), but it continues to be a subject of contention amongst those who believe in its complementarity or substitutional impact on activity-travel behavior (Elldér, 2020). This study adds to this argument by looking at the reasons for telecommuting prior to the pandemic and the changes in the workplace from before to after the pandemic lockdown.

According to the collected sample, 38.1% of participants had the experience of telecommuting more than once a month before the

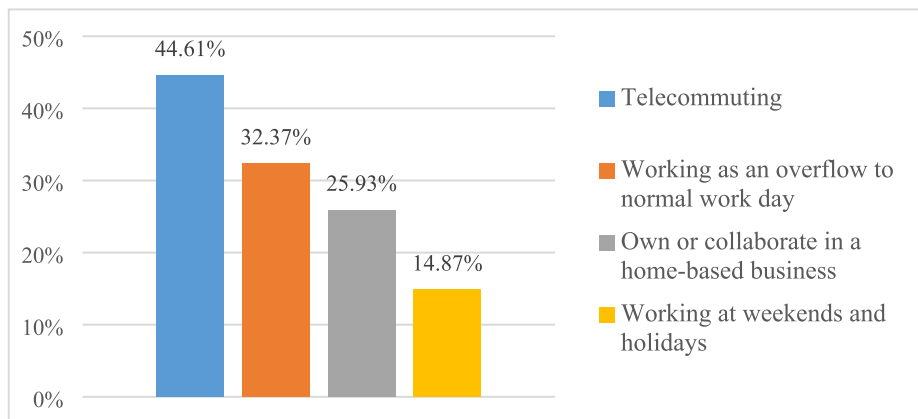


Fig. 11. Distribution of “work from home” types before the lockdown among experienced teleworkers.

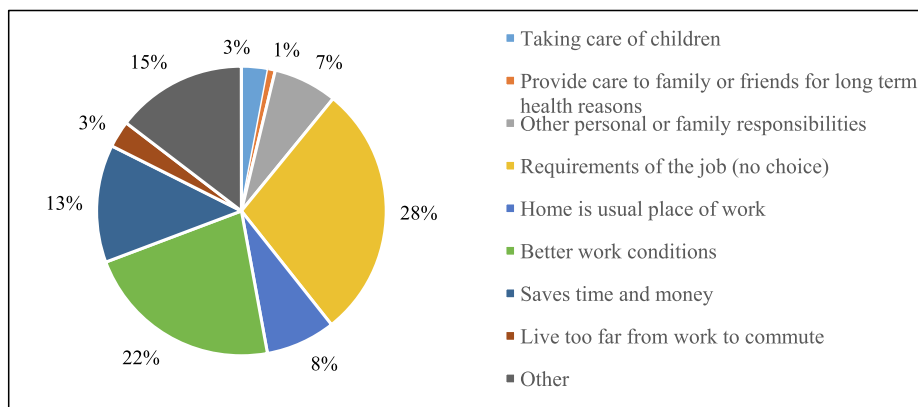


Fig. 12. Statistics Canada 2015 TUS stated reasons for working from home.

COVID-19 pandemic. The frequency distribution of telecommuting is displayed in Fig. 10. According to Fig. 10, 71% of experienced telecommuters use this option every week, and half of them telecommute more than three days each week, indicating that they are regular telecommuters. Also, the participants were asked to identify one of four telecommuting objectives for which they use it (the respondents were able to choose all applicable options). Fig. 11 depicts the distribution of telecommuting types. Telecommuting was used as a substitute for working at a workplace by 45.61% of telecommuters (17% of the total sample), while around 26% contributed to a home-based business. On the other hand, 47.24% of telecommuters used ICT-based alternatives as a complement to their in-place work activity by telecommuting during holidays or after working hours. Before the COVID-19 pandemic, telecommuting was shown to have both substitution and complementary effects on in-place work activities, albeit substitution was the primary effect.

Telecommuting is constrained by a variety of factors such as losing social/professional connections and technological barriers discouraging employees or disabling businesses to utilize it. (see this comprehensive review (Mokhtarian, 2009)). However, there are still incentives to telecommute. For instance, a discussion is presented here on results from the 2015 time use survey (TUS) conducted by Statistics Canada (Statistics Canada, 2017). Among respondents who live in the large urban areas in Ontario ( $N = 4428$ ), 14% of the employed population worked from home in 2015 (at least part-time). The TUS survey finds that 70% of the employed population works a regular daytime shift. The distribution of stated reasons for working from home is provided in Fig. 12. The most common reasons are better working conditions and it being a requirement of the job. These results suggest that those working from home do so for both mandatory and discretionary reasons. Many individuals work from home in order to care for family members (both children and those who have health issues) or other family responsibilities.

The proportion of telecommuters in the collected data is not matched with the TUS survey which is likely due to differences in the framing of the question and an increasing proportion of individuals working from home between 2015 and 2020. However, the proportion of telecommuters who used it as a substitute for in-place work activity matches in both datasets.

The long-lasting global lockdown imposed by COVID-19 presents an unexpected opportunity to boost its appeal. According to the findings, more than 31% of full-time workers who were only working at the workplace before the lockdown, switched to working from home shortly after the lockdown (Fig. 13). Also, 5% of full-time on-site workers chose a hybrid workplace option after the lockdown. Thus, a substitution pattern was detected for work location choice during the pandemic lockdown.

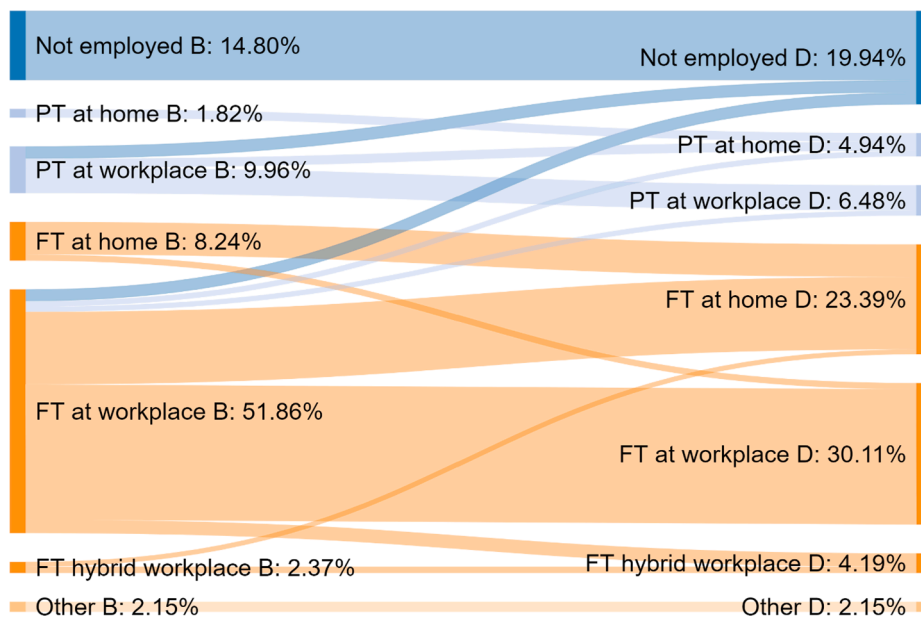


Fig. 13. Comparing work status shortly after lockdown with before lockdown.

The substitution pattern, which this research and many others in the literature (Shamshiripour et al., 2020; Beck and Hensher, 2020) found during the lockdown pandemic, is a signal of changes in working behavior. Although this behavior alteration can be sustained to some extent in the future, it will be inaccurate to generalize that to anticipate the influence of ICT on work activity in the post-pandemic condition (i.e. when COVID-19 is not a treat anymore). That is because telecommuting is forced on the people by the pandemic lockdown, which is neither a fair nor a stable choice situation. Therefore, to measure the choices in a post-pandemic condition, this study implemented a stated preference analysis with a series of pre-designed scenarios, which will be discussed in section 5.

#### 4.5. Attitudinal latent variables

Many attitudinal questions about various topics are included in the collected survey, such as the benefits and drawbacks of working from home or at a traditional workplace, changes in work-related activities since COVID-19 and respondents' feelings about these changes, and COVID-related restrictions and precautions. To include decision-makers' attitudes in statistical analysis, latent variables from these attitudinal questions must be retrieved using factor analysis. Factor analysis is a series of statistical processes for determining the number of unique constructs required to explain the pattern of correlations between a set of variables (Fabrigar and Wegener, 2011).

When there is no clear expectation of the correlation structure, an Exploratory Factor Analysis is required to determine the structure. The optimal number of common factors and the contribution of measures in each factor (factor loadings) might be determined using parallel analysis (i.e. comparing the eigenvalues from observed and completely random data). The weight (load) and mix of measures in each component may then be used to identify and interpret factors (latent variables). To fit the common factor model and establish the factor structure (factor extraction), the Maximum Likelihood technique was employed (Fabrigar and Wegener, 2011). All of the analyses were carried out with the help of several libraries published in the open-source computer language R, most notably Lavaan (Rosseel, 2012) and psych (psych citation info [Internet], 2021).

The next step is to check the reliability of the factors provided by the EFA technique. Internal consistency of the indicators inside the factors (i.e. the indicators within each component assess the same notion) requires reliability testing (Tavakol and Dennick, 2011). Cronbach's Alpha (also known as Tau-equivalent reliability and coefficient alpha) and Coefficient Omega (also known as composite/construct reliability) were used to measure dependability with the satisfactory threshold of  $>0.70$  (Kline, 2015). According to preliminary analysis, some of the factors derived from EFA were not internally consistent. Thus, the extracted factor structure needs to be adjusted. The new factor structure should be tested again in another procedure called Confirmatory Factor Analysis (CFA).

Finally, the CFA structure's fit must be assessed. Only a few tests were chosen from the available possibilities to check the quality of fit: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Standardized Root Mean Square Residual (SRMR), and Tucker–Lewis Index (TLI). Table 5 shows the results of these checks for the CFA-generated factor structure as well as the cutoff values that indicated a satisfactory match. When the results of CFA thresholds (Table 5) are compared, it seems that the structure designed for CFA may pass the tests' criteria. As a result, a few parameters were identified that may be utilized in estimating statistical models in the future. The final factor loadings and factor structure are presented in Table 6.

**Table 5**  
Summary of Values and Thresholds of Goodness-of-fit Measures for Confirmatory Factor Analysis.

	Value	Cutoff
RMSEA	0.057	<0.05 (68)
SRMR	0.039	<0.08 (69)
TLI	0.918	>0.90 (70)
CFI	0.931	>0.90 (69)

**Table 6**  
Factor Structure and Factor Loadings (From CFA).

Factors and Relevant Attitudinal Statements	Factor Loading CFA*
<b>Factor 1: Reasons to Prefer Workplace</b> ( $\alpha = 0.844$ , $\omega = 0.846^{**}$ )	
Better Concentration at Workplace <sup>a</sup>	1.000
Higher Performance at Workplace <sup>a</sup>	1.021
Better Collaboration at Workplace <sup>a</sup>	0.938
Better Socializing at Workplace <sup>a</sup>	0.929
More Facilities at Workplace <sup>a</sup>	0.962
Can Show Higher Commitment by Working at Workplace <sup>a</sup>	0.748
<b>Factor 2: Impact of COVID-19 on Productivity and Concentration</b> ( $\alpha = 0.937$ , $\omega = 0.937$ )	
How your concentration affected <sup>b</sup>	1.000
How your productivity affected <sup>b</sup>	1.008
How your cooperation with your colleagues affected <sup>b</sup>	0.994
<b>Factor 3: Impact of COVID-19 on Work-Related Activities</b> ( $\alpha = 0.739$ , $\omega = 0.745$ )	
Socializing with Colleagues <sup>b</sup>	1.000
Give/Receive Support from Colleagues <sup>b</sup>	1.142
Being Understood by Supervisor <sup>b</sup>	0.913
Workload <sup>b</sup>	0.665
<b>Factor 4: Ties to Workplace</b> ( $\alpha = 0.862$ , $\omega = 0.864$ )	
Maintain Social Connections <sup>a</sup>	1.000
Maintain Professional Connections <sup>a</sup>	1.039
To Not Lose The Opportunities and Promotions <sup>a</sup>	0.909
<b>Factor 5: Health and Safety Measures to Reduce Risk of COVID-19</b> ( $\alpha = 0.771$ , $\omega = 0.772$ )	
Always Wearing Mask <sup>a</sup>	1.000
Avoid Social Gathering <sup>a</sup>	0.955
Maintain Social Distancing <sup>a</sup>	0.884
<b>Factor 6: General Opinion About Telecommuting</b> ( $\alpha = 0.793$ , $\omega = 0.793$ )	
Telecommuting Has More Advantages than Disadvantages <sup>a</sup>	1.000
Telecommuting Should Be More Common <sup>a</sup>	1.017
<b>Factor 7: Feelings About The Impact of COVID-19 on Work-related Activities</b> ( $\alpha = 0.807$ , $\omega = 0.808$ )	
Socializing with Colleagues <sup>c</sup>	1.000
Give/Receive Support from Colleagues <sup>c</sup>	1.171
Being Understood by Supervisor <sup>c</sup>	1.009
Professional Development Program <sup>c</sup>	0.897

\* All estimated loadings are significant at the 95% significance level (Z-value > 1.96).

\*\*  $\alpha$  stands for “ $\alpha$  Cronbach” and  $\omega$  stands for “ $\omega$  coefficient”.

<sup>a</sup> Likert scale from “strongly disagree” to “strongly agree”.

<sup>b</sup> Likert scale from “significantly decreased” to “significantly increased”.

<sup>c</sup> Likert scale from “very unhappy” to “very happy”.

## 5. Models

The data analysis presented above sheds light on the immediate and short-term effects of an interruption on activity-travel behavior alterations and ICT alternative adoption. However, an essential concern about the possible continuity of these newly accepted routines has not been addressed. For that purpose, this section poses two questions and responds to them:

Q1: What are the influential factors in the choice of continuing online grocery shopping in the post-COVID era.

Q2: What are the influential factors in the choice of continuing telecommuting in a post-COVID era.

Two mixed logit models are fitted to the gathered stated preference answers to address these issues. The rest of this section discusses the specification and statistical testing of the estimated models. The next section provides a quick overview of the binary mixed logit model with repeated choices.

This study involves repeated choices from respondents, as each decision-maker is presented with eight stated choice situations in which they must pick between offered possibilities. We utilized the logit model to profit from characteristics of random utility choice models, but this choice case is fundamentally different in two respects from logit. First, there is heterogeneity among the respondents toward each variable. Second, the records of a single individual cannot be presumed to be independent. To overcome these two

**Table 7**  
Grocery Shopping Method Choice, Model Specification and Validation.

	E-Shopping		In-store Shopping	
	Value	t-stats	Value	t-stats
<b>Delivery Fee (base: free)</b>				
free for purchases above \$50	−1.211	−7.448		
\$5 fee	−0.860	−4.888		
<b>Delivery Time (base: &lt; 5 h)</b>				
5 Hours to one day	−0.359	−2.617		
<b>Have Experience in Ordering Online + Home Delivery Before Lockdown (base: no)</b>				
yes	0.825	1.582		
<b>One-way Travel Time to Supermarket</b>				
(base: < 20 min.)				
21–30 min.			−1.099	−6.617
<b>Waiting Time in Line to Enter Supermarket</b>				
(base: < 30 min.)				
more than 30 min.			−0.241	−1.421
<b>One-way Travel Time to Wholesale Market</b>				
(base: < 30 min.)				
31–45 min.			−0.688	−4.630
<b>COVID-19 Vaccination Rate</b>				
(base: some, or all, of the population has the vaccine)				
no vaccine has been found yet			−0.327	−2.139
<b>Crowding Level in Supermarket (base: normal crowding)</b>				
High crowding			−0.868	−6.576
<b>Alternative Specific Constants</b>				
Mean effect	−	−	2.720	10.663
Variance effect	2.195	1.782	2.173	1.784
<b>Statistics</b>				
initial log-likelihood	−1669.3			
final log-likelihood	−1367.6			
$\rho^2$	0.181			
$\bar{\rho}^2$	0.174			

discrepancies, we employed a mixed logit model using respondents' repeated choices (Hess and Rose, 2009; Train, 2003). The probability function is analogous to a sequence of multiplied logit functions, each represents one scenario (Eq. (1)):

$$P_{n,s}(i|\beta) = \prod_{s=1}^8 \frac{e^{-\beta_n x_{i,n,s}}}{\sum_j e^{-\beta_n x_{j,n,s}}} \quad (1)$$

In Eq. (1),  $P_{n,s}(i|\beta)$  gives the choice probability of alternative  $i$  for respondent  $n$  in choice situation  $s$  given parameters  $\beta$ . To get the unconditional probability, equation (1) needs to be integrated the overall values of  $\beta$  (Eq. (2)).

$$P_{n,s}(i) = \int P_{n,s}(i|\beta) f(\beta) d\beta \quad (2)$$

In Eq. (2),  $f(\beta)$  is density function. A Monte Carlo simulation method was employed to estimate the parameters of this model.

### 5.1. Grocery shopping method choice

The essential requirement for food consumption throughout the two-month shutdown ensured demand for grocery shopping. The danger of becoming ill while buying in-person, on the other hand, may motivate customers to investigate e-shopping. Having the option of purchasing in-store or online gives shoppers a choice when it comes to grocery shopping. By simulating grocery shopping shortly after the reopening, a better understanding may be gained of the long-term impact of COVID-19 disruption on shopping behavior and identify potential influential factors. To answer question 1, it has been chosen a subset of respondents who did not utilize online grocery shopping (with home delivery or self-pickup) more than once per month prior to the pandemic (46% of the sample). To study the decision between online and in-store shopping, a binary logit model is calculated. Since the data contains eight option records for each respondent, a panel model is utilized to capture the heterogeneity effect. The model output is summarized in Table 7.

The parameters have intuitivsigns and all but two are statistically significant. The increased value placed on a delivery cost on sales over \$50 in comparison to a flat \$5 price can be rationalized as follows: Establishing a minimum purchase value is a sort of restriction since it compels consumers to acquire products they do not require in order to reach the minimum purchase value of \$50. A high degree of congestion and a lack of vaccination have a detrimental effect on the utility of in-store shopping, as it implies that consumers continue to be concerned about becoming sick when they choose this option. Travel time to both types of stores is, as predicted, negative. The trip time parameter is greater for supermarkets than for wholesale marketplaces, implying that consumers value the additional items available at the wholesale market. Waiting time is not considered a key variable by the majority of respondents in comparison to the time required to drive to the business.



**Table 8**  
Workplace Choice Model Specification and Validation.

	Telecommute		Hybrid Workplace		Workplace	
	Value	t-stats	Value	t-stats	Value	t-stats
<b>Furniture at Home</b> (base: dining table and chair)						
work desk and chair	0.49	2.41	0.379	1.84		
fully furnished office room	*	*	*	*		
<b>Technologies at Home</b> (base: PC/Laptop)						
PC/Laptop and Internet	0.385	2.05	0.189	0.987		
PC/Laptop and Internet and printer	*	*	*	*		
<b>Shifting Workhour</b> (base: not allowed)						
allowed	*	*	*	*	*	*
<b>Splitting Workhour</b> (base: not allowed)						
allowed	−0.815	−5.14	−0.312	−1.94		
<b>COVID-19 Vaccination Rate</b> (base: everyone has been vaccinated)						
80% of people have been vaccinated					*	*
40% of people have been vaccinated					−0.786	−3.68
no one has been vaccinated					−0.322	−1.55
<b>Child Caring</b> (base: in-home without nanny)						
in-home with nanny	−0.453	−1.15	−0.715	−1.82	0.637	1.72
child care	−0.442	−1.12	−0.618	−1.56	0.554	1.51
<b>One-way travel time to the workplace</b> (base: greater than 30 min)						
Below 30 min			*	*	*	*
			0.348	2.21	0.933	3.94
			*	*	*	*
<b>Crowding</b> (base: normal crowding)						
Low			*	*	*	*
High			−0.27	−2.03	−0.414	−2.11
<b>Gender</b> (base: male)						
female	1.08	2.95	0.852	2.6		
<b>Age group</b> (base: below 30/ 40 to 49/ above 65)						
Age 2			−0.183	−0.642		
3			−0.476	−1.5		
4			−1.27	−4.28		
5			−1.83	−4.95		
Age between 50 and 64						
<b>Education level</b> (base: high school or below)						
diploma/certificate	*	*	*	*	*	*
bachelor degree	0.891	2.32	0.974	2.86		
master/Ph.D. degree	*	*	*	*		
<b>Work Status Before Lockdown</b> (base: Not employed)						
full-time telecommuting	1.02	3.7				
part-time telecommuting	0.527	1.04				
full-time hybrid workplace			*	*		
part-time hybrid workplace			*	*		
full-time at workplace					2.09	5.6
part-time at workplace					2.23	3.4
<b>Occupation Type Before Lockdown</b> (base: other employments)						
administration			0.642	2.04		
management			0.484	1.55		
technology			0.952	2.16		
<b>Alternative Specific Constants</b>						
Mean effect	2.54	4.78	2.16	3.88		
Variance effect	2.02	14.9	*	*	2.63	12.1
<b>Statistics</b>						
initial log-likelihood	−3185.562					
final log-likelihood	−2713.357					
$\rho^2$	0.148					
$\bar{\rho}^2$	0.131					

\* Not significant.

## 5.2. Workplace choice

To answer question 2 from above, we questioned the respondent to state their preferred workplace. As presented in Table 1, each scenario has three possible options to choose from. The specification and statistics of the binary mixed logit model are presented in Table 8.

During the model estimation procedure, all of the SP scenarios' attributes were examined. As seen in Table 8, several of the attributes or their levels were determined to be insignificant. While the model findings indicate that the option of moving work hours does not affect choice, the option of dividing work hours appears uninteresting to many respondents and may result in disutility.

Additionally, when persons have access to suitable office furniture such as a work desk/chair and basic technical equipment such as a PC/Laptop and steady internet, the results support the desire of WHF.

The model demonstrates an intriguing correlation between teleworking choice and the COVID vaccination rate. Concerns about COVID-19 and the detrimental impact of low vaccination rates were mirrored in respondents' perceptions of on-site workplace usability. It is worth noting that when the vaccination rate is 40%, the magnitude of the parameter is bigger than when no vaccine has been discovered. In other words, respondents appear less interested in working on-site after 40% of people got vaccinated, most likely because the danger of infection is high but the health precaution is not. Additionally, when the office is extremely packed, the on-site solution loses some utility. Access to daycare is critical for parents who prefer to work in the workplace. On the other hand, it appears as though caring for children at home and avoiding interaction with people outside the safe bubble is more appealing to telecommuters and hybrid workplace employees. As predicted, shorter travel times can alleviate the inutility of office travel.

Additionally, various sociodemographic factors were examined throughout the model estimation process. Males were shown to be more reliant on on-site jobs. Age was shown to have a negative correlation with the utility of technology-based alternatives, although a greater degree of education had a favorable correlation. Additionally, the model suggests that employment choice was impacted by the permanent workplace prior to the pandemic, while certain occupations were found to be more amenable to ICT owing to their inherent compatibility. Finally, teleworking appears to be challenging for senior workers and has a strong negative effect on WFH selection.

## 6. Conclusions

This study represents a comprehensive assessment of activity-travel behavior alteration as a result of the COVID-19 pandemic. The survey instrument includes both revealed preference and stated preference components to capture both existing and anticipated future behavior. The focus of the study was to examine the effects of ICT on transportation choices. We find that, in the case of food consumption, ICT options were replaced by at-home preparation, likely because individuals wanted to reduce their exposure to others. Regarding online shopping for groceries, respondents expressed a preference for a flat shipping fee of \$5 rather than free shipping on purchases over a dollar threshold. However, this preference is likely correlated with income and at what level the threshold is set. Future research could examine this relationship in more detail.

Our analysis suggests that in-person grocery shopping will continue to be substituted by online options so long as a vaccine is unavailable. Respondents expressed a preference for completing their shopping at stores with more variety (i.e., wholesale stores rather than supermarkets) and are willing to travel longer to reach these stores. Respondents are interested in working at home, but this option requires flexibility from their employer and the availability of adequate office furniture at home. While a sizable fraction of people who worked at the workplace prior to the lockdown are practicing telecommuting, a significant number of individuals still needed to travel to their workplace. Whether this distribution persists is yet to be determined, but there is a clear need to provide safe transportation facilities for those who continue to travel. Finally, it is found that the availability of childcare increased the preference for returning to the workplace. As we evaluate the response to the COVID-19 pandemic, childcare is likely to be an important area for government investment to accommodate the workplace preferences of individuals with children.

This study tends to reflect the impact of the COVID-19 pandemic on our activity-travel behavior by focussing on our most frequent daily activities. Some of the activities explored in this study were neglected by the previous studies in the literature. The estimated random utility models benefit from the mixed structure to address the heterogeneity of respondents in choosing their workplace and shopping method. The information presented in this article not only helps to improve understanding of ongoing pandemic conditions but also provides a sense of individuals' behavior in the post-COVID era. Also, the findings of this study can be beneficial to anticipate the impact of similar disruptions on activity behavior in the future.

Further analysis is required to investigate the long-term impact of this pandemic on the activity-travel schedule of individuals. Also, investigating the persistence of individual behavior in the post-COVID-19 era is necessary to determine if in-home activities would last as a chosen routine or if it was the only option to continue activities during the lockdown.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Author contributions

The authors confirm contribution to the paper as follows: study conception and design: A. Dianat, J. Hawkins, and K. M. N. Habib; Analysis and interpretation of results: A. Dianat and J. Hawkins; Draft manuscript preparation: A. Dianat, J. Hawkins, and K. M. N. Habib. All authors reviewed the results and approved the final version of the manuscript.

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